U.S. Army Center for Health Promotion
and Preventive Medicine

USCHPPM

Development of Terrestrial Exposure and Bioaccumulation Information for the Army Risk Assessment Modeling System (ARAMS)

APRIL 2004

Prepared for
Contract No. DAAD050-00-P-8365

U.S. Army Center for Health Promotion and Preventive Medicine

Toxicology Directorate

Health Effects Research Program

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Readiness Thru Health

Report

Development of Terrestrial Exposure and Bioaccumulation Information for the Army Risk Assessment Modeling System (ARAMS)

Submitted to

Health Effects Research Program

April 2004

CH2MHILL

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Acknowledgements

We thank the following for significant contributions to this document: Christine Arenal, Bradley E. Sample, David Ziolkowski, and all previous authors who have contributed to the Wildlife Exposure Factors Handbooks and other significant works that have formed the basis of this report.

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When referencing this document use the following citation:
USACHPPM. 2004. Development of Terrestrial Exposure and Bioaccumulation Informaion for the Army Risk Assessment Modeling System (ARAMS). U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) Contract Number DAAD050-00-P-8365, Aberdeen Proving Ground, Maryland, 2004.

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SECTION 1

Introduction

Human and environmental health assessment is important when making decisions regarding land maintenance and stewardship. The U.S. Army controls a significant portion of land, much of which is habitat to wildlife species. Some of this land supports threatened and endangered species of birds and mammals. In order to make wise land use decisions regarding these animals, potential exposure of substances as a result of past or present military activities must be evaluated. Assessment of risks to wildlife (i.e., birds and mammals) is also key component of ecological risk assessment; an integral process in the Defense Environmental Restoration Program. To evaluate risks to wildlife, modeling of exposure estimates is required.

Exposure can be defined as the coincidence in both space and time of a receptor and a stressor such that the receptor and stressor come into contact and interact (Risk Assessment Forum 1992). In the context of ecological risk assessment, receptors include all endpoint species or communities identified for a site (see Suter et al. 2000 for discussions of ecological endpoints for contaminated sites). In the context of U.S. Army site assessments, stressors are chemical contaminants and the contact and interaction are represented by the uptake of the contaminant by the receptor. Without sufficient exposure of the receptor to the contaminants, there is no ecological risk.

Unlike other organisms, terrestrial wildlife may be significantly exposed to contaminants in multiple media. They may drink or swim in contaminated water, ingest contaminated food and soil, and breathe contaminated air. Exposure models for terrestrial wildlife must, therefore, include multiple media. In addition, because most wildlife are mobile, moving among and within habitats, exposure is not restricted to a single location. They may integrate contamination from several spatially discrete sources. As a consequence, the accurate estimation of wildlife exposure requires the consideration of habitat requirements and spatial movements.

The purpose of this report is to compile the information necessary to describe the exposure of terrestrial wildlife to contaminants most likely to occur in environmental investigations of U.S. Army installations (USA CHPPM, 2000). These contaminants include those of military relevance (e.g., energetic compounds and their breakdown products) and others of concern, such as metals. Reptiles and amphibians have not traditionally been included as receptors because few data exist with which to assess exposure to these organisms. However, the information database for these species is expanding. However, because toxicological data are scarce for both classes, extrapolation of these data across taxonomic orders is problematic. The general exposure estimation procedure developed for birds and mammals, however, is applicable to reptiles and amphibians (EPA, 1993).

Methods are presented for estimating exposure of wildlife receptors to chemical contaminants (Section 2). In addition to exposure models, life history parameters of selected species (Section 3) and models to estimate contaminant concentrations in selected food types consumed by wildlife (Section 4) needed to accurately estimate exposure are presented.

SECTION 2

Methods for Estimation of Exposure

As wildlife move through the environment, they may be exposed to contamination via three pathways: oral, dermal, and by inhalation. Oral exposure occurs through the consumption of contaminated food, water, or soil. Dermal exposure occurs when contaminants are absorbed directly through the skin. Inhalation exposure occurs when volatile compounds or fine particulates are respired into the lungs. The total exposure experienced by an individual is the sum of exposure from all three pathways or

$$E_{total} = E_{oral} + E_{dermal} + E_{inhal}, \quad (1)$$

where,

E_{total} = total exposure from all pathways,

E_{oral} = oral exposure,

E_{dermal} = dermal exposure,

E_{inhal} = exposure through inhalation.

Dermal exposure is assumed to be negligible for birds and mammals in most ecological risk assessments. While methods are available to assess dermal exposure to humans (EPA 1992), data necessary to estimate dermal exposure are generally not available for wildlife (EPA 1993). Additionally, some contaminants found at U.S. Army facilities (e.g., metals) are unlikely to be absorbed through skin (Camner et al., 1979; Watters et al., 1980). The feathers of birds and the fur of mammals further reduce the likelihood of significant dermal exposure by limiting the skins contact with contaminated media. Therefore, dermal exposure is expected to be negligible relative to other routes in most cases. If contaminants that have a high affinity for dermal uptake are present (e.g., organic solvents and pesticides) and an exposure scenario for an endpoint species is likely to result in significant dermal exposure (e.g., burrowing mammals or amphibians), dermal exposure may be estimated using the model for terrestrial wildlife presented by Hope (1995).

Inhalation of contaminants is also assumed to be negligible in most ecological risk assessments for two reasons. First, because most contaminated sites are either capped or vegetated, exposure of contaminated surface soils to winds and resulting aerial suspension of contaminated dust particulates are minimized. Second, most volatile organic compounds (VOCs), rapidly volatilize from soil and surface water to air, where they are rapidly diluted and dispersed. Paterson et al. (1990) suggest that organic compounds with soil half-lives of <10 days are generally lost from soil before significant exposure can occur. As a consequence, significant exposure to VOCs through inhalation is unlikely. In situations where inhalation exposure of endpoint species is believed to be occurring or is expected to occur, models for vapor or particulate inhalation (Hope 1995) may be employed. In these cases, the Environmental Protection Agency (EPA) (1993) recommends consulting an inhalation toxicologist. Recently, inhalation benchmarks for 15 substances were derived for the red fox (*Vulpes fulva*) and the gray bat (*Myotis grisescens*). These benchmarks were used in the ecological risk assessment for incineration of chemical weapons at the Anniston Chemical Disposal Facility, Alabama (USA CHPPM, 1999).

Because contaminant exposure experienced by wildlife through both the dermal and inhalation pathways is considered negligible (except in certain circumstances), the majority of exposure is attributed to the oral exposure pathway. Equation 1 can therefore be simplified to

$$E_{total} \approx E_{oral}\ . \tag{2}$$

2.1 Estimation of Oral Exposure

Oral exposure experienced by wildlife may come from multiple sources. They may consume contaminated food (either plant or animal), drink contaminated water, or ingest soil. Soil ingestion may be incidental while foraging or grooming or purposeful to meet nutrient needs. The total oral exposure experienced by an individual is the sum of the exposures attributable to each source and may be described as

$$E_{oral} \approx E_{food} + E_{water} + E_{soil}, \tag{3}$$

where,

E_{food} = exposure from food consumption,

E_{water} = exposure from water consumption,

E_{soil} = exposure from soil consumption.

By replacing E_{oral} with a generalized exposure model modified from Suter et al. (2000), the previous equation can be rewritten as follows:

$$E_j = \left[Soil_j \times P_s \times FIR\right] + \left[\sum_{i=1}^{N} B_{ij} \times P_i \times FIR\right] + \left[Water_j \times WIR\right] \tag{4}$$

where,

E_j = total exposure to chemicals (mg/kg/d)

$Soil_j$ = concentration of chemical (j) in soil (mg/kg)

P_s = soil ingestion rate as proportion of diet

FIR = species-specific food ingestion rate (kg food/kg body weight/d)

B_{ij} = concentration of chemical (j) in biota type (i) (mg/kg)

P_i = proportion of biota type (i) in diet

$Water_j$ = concentration of chemical (j) in water (mg/L)

WIR = species-specific water ingestion rate (L/kg body weight/d)

The product of the model is a dosage expressed as amount of chemical per kilogram receptor body weight per day (mg/kg/d).

If the site is spatially heterogeneous with respect to either contamination or wildlife use, the model must be modified to include spatial factors. The most important spatial consideration is the movement of wildlife. Animals travel varying distances, on a daily to seasonal basis, to find food, water, and shelter. The area encompassed by these travels is defined as the home range (we use the term here to include territories). If the site being assessed is larger than the home range of an endpoint species and provides the habitat needs of the species, then the previously listed models are adequate. However, endpoint species often have home ranges that are larger than contaminated sites, or the contaminated site may not supply all of a species' habitat requirements. In those cases, the wildlife exposure model may be modified as described in Suter et al. (2000). Generally, these modifications require knowledge of the spatial extent of the contamination, proportion of suitable habitat within the contaminated area, and home range size of the endpoint species.

2.2 Exposure-Modifying Factors

Factors other than those described in these models modify contaminant exposure experienced by wildlife endpoint species. These factors include age, sex, season, and behavior patterns.

The models above imply that the endpoint species have uniform body size, metabolism, diet, home ranges, and habitat requirements. However, these properties may differ between juveniles and adults and between males and females. For example, because they are actively growing, metabolism (and therefore food consumption) is generally greater for juveniles of most endpoint species. Diet composition may also differ dramatically between juveniles and adults of the same species. Similarly, the food requirements of females during reproduction are greater than those for males for many endpoint species. These factors may serve to make certain age classes or a particular sex experience greater contaminant exposure than other segments of the population. Because of their greater exposure, contamination may present a greater risk to these segments of the population. If it is known that a particular lifestage or sex is sensitive to contamination, that lifestage should be emphasized in the exposure assessment.

Behavior may modify exposure by increasing or decreasing the likelihood of contact with contaminated media. Wildlife behaviors are frequently seasonal in nature. Some foods may be available and consumed only at certain times of the year. Similarly, some habitats and certain parts of the home range may be used only in certain seasons. In addition, many species hibernate or migrate; by leaving the area or restricting their activity to certain times of year, their potential exposure may be dramatically reduced. All of these factors should be considered when evaluating contaminant exposure experienced by wildlife, and exposure models should be adjusted accordingly. The simplest approach to modifying the exposure estimates to take into account some of these exposure-modifying factors is to generate multiple exposure estimates. For example, if diet differs by season or by sex, calculate exposure estimates for each sex or season. Comparison of exposure estimates generated for differing exposure scenarios will aid in identifying the segments of population at greatest risk or times of year when risk is greatest.

SECTION 3

Life History Parameters for Selected Species

To estimate contaminant exposure by terrestrial wildlife using the models described above, species-specific values for the parameters are needed. Because of large within-species variation in values for life-history parameters, data specific to the site in question provides the most accurate exposure estimates and should be used whenever available. Because availability of site-specific life history data is extremely limited, published values from other areas within an endpoint species range must generally be used to estimate exposure.

Life history parameters that determine contaminant exposure have been outlined for four mammals and six birds that have not been described in previous sources (Table 3-1). These species were selected because they are likely to occur at U.S. Army facilities (species occurrence will vary according to location of site however) and are considered to be potential endpoints at selected U.S. Army facilities. We have also included existing species accounts reported in the "Wildlife Exposure Factors Handbook" (EPA, 1993) and in the "Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants" (Sample et al., 1997a). EPA (1993) presents life history data for 15 birds, 11 mammals, and 8 reptiles or amphibians (Table 3-2) and Sample et al. (1997a) presents eight mammals and five birds (Table 3-3). Brief summaries of life history parameters for selected wildlife species on the Oak Ridge Reservation (ORR) are presented in Sample and Suter (1994), but are not included in this report. Other sources of life history summaries include the Mammalian Species series (published by the American Society of Mammologists) and the Birds of North America series (published by the American Ornithologists Union and the Philadelphia Academy of Natural Sciences). The Mammalian Species series currently addresses over 300 mammal species, while Birds of North America series addresses 240. Additional information on the Birds of North American may be obtained from the Internet: http://www.acnatsci.org/bna/.

TABLE 3-1
New U.S. Army Relevant Receptor Species

Birds	Mammals
Black-crowned Nightheron	Desert Shrew
Wild Turkey	Big Brown Bat
Mourning Dove	Pocket Gopher spp.
Roadrunner	Northern Grasshopper Mouse
Northern Flicker	
Red-winged Blackbird	

TABLE 3-2
Summary of Species Presented in the *Wildlife Exposure Factors Handbook* (EPA, 1993)

Birds	Mammals	Reptiles or Amphibians
Great Blue Heron	Short-tailed Shrew	Snapping Turtle
Canada Goose	Red Fox	Painted Turtle
Mallard Duck	Raccoon	Eastern Box Turtle
Lesser Scaup	Mink	Racer
Osprey	River Otter	Northern Water Snake
Red-Tailed Hawk	Harbor Seal	Eastern Newt
Bald Eagle	Deer Mouse	Green Frog
American Kestrel	Prairie Vole	Bullfrog
Northern Bobwhite Quail	Meadow Vole	
American Woodcock	Muskrat	
Spotted Sandpiper	Eastern Cottontail Rabbit	
Herring Gull		
Belted Kingfisher		
Marsh Wren		
American Robin		

TABLE 3-3
Summary of Species Presented in Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants (Sample et al., 1997a)

Birds	Mammals
Green Heron	Little Brown Bat
Burrowing Owl	Great Basin Pocket Mouse
Cooper’s Hawk	Pine Vole
Western Meadowlark	Black-tailed Jackrabbit
Swallows (tree, violet-green, bank, northern rough-winged, purple martin, cliff, and cave)	Mule Deer
	Coyote
	Kit Fox
	weasels (long-tailed, short-tailed, and least)

3.1 Estimating Exposure Parameters For Wildlife

Implementation of the exposure model presented in Eq. 4 requires the specification of certain species-specific parameters. Although some parameters such as body weight must be obtained from the literature for each endpoint species, general methods are available for estimating food and water consumption rates, inhalation rates, and home range/territory size. These methods are described below and have been utilized as indicated in the species accounts presented in this section.

3.1.1 Body Weight

Body weight is an extremely important parameter in the estimation of exposure. Not only is it a factor in determining the exposure rate, but because metabolism and body weight are related, body weights may be used to predict food and water consumption rates. On a per individual basis, larger animals consume more food or water than do smaller animals. However, because larger animals have lower metabolic rates than smaller ones, smaller animals have higher food and water consumption rates per unit body weight. This means that smaller animals will experience greater oral exposure per unit body weight than will larger animals. Body weights for selected terrestrial wildlife are reported in EPA, (1993). Additional sources include: Dunning (1984, 1993), Burt and Grossenheider (1976), Silva and Downing (1995), the Mammalian Species series, published by the American Society of Mammalogists, and the Birds of North America series, published by the American Ornithologists Union and the Philadelphia Academy of Natural Sciences.

3.1.2 Estimation of Food and Water Consumption Rates

Field observations of food, water, or soil consumption rates are the best data to use to estimate exposure. With very few exceptions, these data are unavailable for most wildlife species. The second best data to use to estimate exposure are media consumption rates for wildlife species derived from laboratory studies. These data are limited because the influence of ambient conditions, such as activity regimes or environmental variables (temperature, humidity, etc.), on metabolism (and therefore consumption rates) are difficult to approximate in a laboratory setting.

In the absence of experimental data, food consumption values can be estimated from allometric regression models based on metabolic rate. Nagy (1987) derived equations to estimate food consumption (in kg dry weight) for various groups of birds and mammals.

$$FIR = (0.0687(BW_{kg})^{0.822})/BW_{kg} \quad \text{Placental Mammals,} \tag{5}$$

$$FIR = (0.0306(BW_{kg})^{0.564})/BW_{kg} \quad \text{Rodents,} \tag{6}$$

$$FIR = (0.0875(BW_{kg})^{0.727})/BW_{kg} \quad \text{Herbivores,} \tag{7}$$

$$FIR = (0.0514(BW_{kg})^{0.673})/BW_{kg} \quad \text{Marsupials,} \tag{8}$$

$$FIR = (0.0582(BW_{kg})^{0.651})/BW_{kg} \quad \text{All Birds,} \tag{9}$$

and

$$FIR = (0.0141(BW_{kg})^{0.850})/BW_{kg} \quad \text{Passerine Birds,} \tag{10}$$

where

FIR = food ingestion rate (kg food [dry weight]/kg body weight/d),

BW_{kg} = body weight (kg live weight).

Recently, Nagy et al., (1999) has developed allometric regression models to calculate the field metabolic rates (FMR) for wild terrestrial vertebrates including birds, mammals, and reptiles.

$$FMR = (4.21(BW_g)^{0.772})/BW_g \quad \text{Placental Mammals,} \tag{11}$$

$$FMR = (5.48(BW_g)^{0.712})/BW_g \quad \text{Rodents,} \tag{12}$$

$$FMR = (7.94(BW_g)^{0.646})/BW_g \quad \text{Herbivores,} \tag{13}$$

$$FMR = (10.1(BW_g)^{0.59})/BW_g \quad \text{Marsupials,} \tag{14}$$

$$FMR = (10.5(BW_g)^{0.681})/BW_g \quad \text{All Birds,} \tag{15}$$

$$FMR = (10.4(BW_g)^{0.68})/BW_g \quad \text{Passerine Birds,} \tag{16}$$

and

$$FMR = (0.196(BW_g)^{0.889})/BW_g \quad \text{All Reptiles,} \tag{17}$$

where,

FMR = field metabolic rate (kJ/d),

BW_g = body weight (g live weight).

The FMR is given in kilojoules per day. Although conversion of the FMR to FIR was not performed as part of the Nagy et al., (1999) paper, FIR-based allometric regression models for selected groups of species have been developed based on the data in Nagy et al. (1999)(EPA, 2000). These models use the FMR, body weight, and average metabolizable energy efficiency values reported in Nagy et al., (1999).

Food ingestion rates estimated using these allometric equations are expressed as kilograms of dry weight. Because wildlife do not generally consume dry food (unless being maintained in the laboratory), food consumption must be converted to kilograms of fresh weight by adding the water content of the food. Percent water content of wildlife foods are listed in Table 3-4. Additional data may be obtained from the literature (e.g., Bell, 1990; Redford and Dorea, 1984; Odum, 1993; and Holmes, 1976). Calculation of food consumption in kilograms of fresh weight is performed as follows.

$$FIR_f = \sum_{i=1}^{m} (P_i \, x \, \frac{FIR}{1 - WC_i}), \tag{18}$$

where,

FIR_f = total food ingestion rate (kg food [fresh weight]/kg body weight/d),

m = total number of food types in the diet,

P_i = proportion of the i^{th} food type in the diet,

WC_i = percent water content (by weight) of the i^{th} food type.

Water consumption rates can be estimated for mammals and birds from allometric regression models based on body weight (Calder and Braun, 1983)

$$WIR = (0.099(BW)^{0.90})/BW_{kg} \quad \text{Mammals,} \tag{19}$$

and

$$WIR = (0.059(BW)^{0.67})/BW_{kg} \quad \text{Birds,} \tag{20}$$

where,

WIR = water ingestion rate (L water/kg body weight/d),

BW = body weight (kg live weight).

TABLE 3-4
Percent Water Content of Wildlife Foods[a]

		Percent Water Content		
	Food Type	**Mean**	**STD**	**Range[b]**
Aquatic invertebrates	Bivalves (w/o shell)	82	4.5	
	Crabs (w/shell)	74	6.1	
	Shrimp	78	3.3	
	Isopods, amphipods			71-80
	Cladocerans			79-87
Aquatic vertebrates	Bony fishes	75	5.1	
	Pacific herring	68	3.9	
Aquatic plants	Algae	84	4.7	
	Aquatic macrophytes	87	3.1	
	Emergent vegetation			45-80
Terrestrial invertebrates	Earthworms (depurated)	84	1.7	
	Grasshoppers, crickets	69	5.6	
	Beetles (adult)	61	9.8	
Mammals	Mice, voles, rabbits	68	1.6	
Birds	Passerines (w/typical fat reserves)			68
	Mallard duck (flesh only)			67
Reptiles and amphibians	Snakes, lizards			66
	frogs, toads	85	4.7	
Terrestrial plants	Monocots: young grass			70-88
	Monocots: mature dry grass			7-10
	Dicots: leaves	85	3.5	
	Dicots: seeds	9.3	3.1	
	Fruit: pulp, skin	77	3.6	

[a] From EPA (1993).
[b] Single values indicate only one value available.

3.1.3 Estimation of Inhalation Rates

Similar to food and water ingestion, allometric equations, based on body mass, have also been developed to estimate inhalation rates of resting mammals (Stahl, 1967) and nonpasserine birds (Lasiewski and Calder, 1971).

$$I_a = (0.54576(BW_{kg})^{0.8})/BW_{kg} \quad \text{Mammals,} \tag{21}$$

and

$$I_a = (0.40896(BW_{kg})^{0.77})/BW_{kg} \quad \text{Non-passerine Birds.} \tag{22}$$

where,

I_a = inhalation rate (m^3 air/kg body weight/d),

BW_{kg} = body weight (kg live weight).

The applicability of Eq. 22 for estimating inhalation rates of passerines is not known. However, the similarity between the models for mammals and birds suggests that Eq. 22 is likely to be suitable for passerines.

3.1.4 Soil Consumption

In addition to consuming food and water, many wildlife consume soil. Soil consumption may occur inadvertently while foraging (i.e., predators of soil invertebrates ingesting soil adhering to worms, grazing herbivores consuming soil deposited on foliage or adhering to roots) or grooming, or purposefully to meet nutrient requirements. Diets of many herbivores are deficient in sodium and other trace nutrients (Robbins, 1993). Ungulates, such as white-tailed deer (*Odocoileus virginianus*) have been observed to consume soils with elevated sodium levels, presumably to meet sodium needs (Weeks, 1978). Because soils at waste sites may contain very high contaminant concentrations, direct ingestion of soil is potentially a very significant exposure pathway. In contrast to food and water consumption, generalized models do not exist with which to estimate soil ingestion by wildlife. Beyer et al. (1994) report soil consumption estimates for 28 wildlife species. Additional data concerning soil consumption are reported in Arthur and Alldredge (1979), Garten (1980c), Thornton and Abrahams (1983), Arthur and Gates (1988), and Calabrese and Stanek (1995).

3.1.5 Estimation of Home Range and Territory Size

Home ranges and territories represent the spatial areas occupied by wildlife. These areas provide each species with food, water, and shelter and may or may not be defended. Home range or territory size is a critical component in estimating exposure. Species with limited spatial requirements (e.g., small home ranges or territories) may live exclusively within the bounds of a contaminated site and therefore may experience high exposure. Conversely, species with large home ranges may travel among and receive exposure from multiple contaminated sites.

Multiple factors may influence home range or territory size. These factors include habitat quality, prey abundance, and population density. Methods have been developed to estimate home range size. McNab (1963) observed that home range size in mammals was a function of body weight.

$$HR = 6.76\,(BW_{kg})^{0.63}, \tag{23}$$

where,

HR = home range (acres),

BW_{kg} = body weight (kg live weight).

Differences in home range requirements were observed between "hunters" (includes species that rely on widely distributed foods, e.g., granivores, frugivores, insectivores, and carnivores) and "croppers" (species that rely on foods that are spatially more concentrated, e.g., grazing and browsing herbivores; McNab, 1963). Home ranges of "hunters" may be as much as 4 times greater than that of "croppers" of the same body mass. Home ranges for each group may be estimated using the following models:

$$HR_h = 12.6\,(BW_{kg})^{0.71}, \tag{24}$$

and

$$HR_c = 3.02(BW_{kg})^{0.69}, \tag{25}$$

where,

HR_h = home range for hunters (acres),

HR_c = home range for croppers (acres).

Note: 1 acre = 0.4047 ha = 4,047 m^2.

More recent research by Harestad and Bunnell (1979) produced the following relationships between body mass and home range in mammals:

$$HR_{herb} = 0.002\,(BW_g)^{1.02}, \tag{26}$$

$$HR_{omn} = 0.59(BW_g)^{0.92}, \tag{27}$$

and

$$HR_{carn} = 0.11(BW_g)^{1.36}, \tag{28}$$

where,

HR_{herb} = home range for herbivores (ha),

HR_{omn} = home range for omnivores (ha),

HR_{carn} = home range for carnivores (ha),

BW_g = body weight (g).

A strong positive relationship also exists between body mass and territory or home range size among birds (Schoener, 1968). Predators tend to have larger territories than omnivores or herbivores of the same weight. Territory size also increases more rapidly with body weight among predators than among omnivores or herbivores. Schoener (1968) believes these relationships reflect the higher density of available food for omnivores and herbivores. While Schoener (1968) developed regression models describing the relationship between body size, home range size, and foraging habits, all parameters needed to implement the models are not presented. A summary of home range or territory sizes for 77 species of land birds (and source references) is included however.

3.2 Mammals

3.2.1 Northern short-tailed shrew (*Blarina brevicauda*)[1]

The northern short-tailed shrew is in the order Insectivora, family Soricidae. Shrews are small insectivorous mammals that inhabit most regions of the United States. They have high metabolic rates and can eat approximately their body weight in food each day. Most species are primarily vermivorous and insectivorous, but some also eat small birds and mammals.

Distribution

The northern short-tailed shrew ranges throughout the north-central and northeastern United States and into southern Canada (George et al., 1986).

Body Size and Weight

The short-tailed shrew is the largest member of the genus, with some weighing over 22 g (George et al., 1986). Short-tailed shrews are 8 to 10 cm in length with a 1.9 to 3.0 cm tail (Burt and Grossenheider, 1980). Some studies have found little or no sexual dimorphism in size (Choate, 1972), while other reports show that males are slightly larger than females (George et al., 1986; Guilday, 1957).

TABLE 3-5
Body Weights (g) for the Northern Short-Tailed Shrew, *Blarina brevicauda*

Location	Sex	N	Mean	Range	Reference
New Hampshire	Both		15.0 ± 0.78		Schlesinger & Potter, 1974
Pennsylvania	Male (Summer)		$19.21 \pm .42$	17.0-22.0	Guilday, 1957
	Female (Summer)		$17.40 \pm .48$	14.0-21.0	
	Male (Fall)		16.87 ± 0.21	13.0-22.0	
	Male (Fall)		15.58 ± 0.23	12.5-22.5	
Maryland/lab	neonate			0.67-1.29	Blus, 1971

Food Habits and Diet Composition

The short-tailed shrew is primarily carnivorous. Common prey items include insects, worms, snails, and other invertebrates and also may eat mice, voles, frogs, other vertebrates and occasionally plants and fungi (Robinson and Brodie, 1982; Hamilton, 1941; Whitaker and Ferraro, 1963). Small mammals are consumed more when invertebrates are less available (Allen, 1938; Platt and Blakeley, 1973, cited in George et al., 1986). Shrews are able to prey on

[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

small vertebrates because they produce a poison secretion in their salivary glands that is transmitted during biting (Pearson, 1942, cited in Eadie, 1952). Because they prey on other vertebrates, shrews can concentrate DDT (and presumably other bioaccumulative chemicals) to levels 10 times higher than either *Peromyscus* or *Clethrionomys* (Dimond and Sherburne, 1969).

The short-tailed shrew stores food, especially in the autumn and winter (Hamilton, 1930; Martin, 1984). Robinson and Brodie (1982) found that short-tailed shrews cached most (86.6 percent) of the prey captured; only 9. 4 percent was consumed immediately. Short-tailed shrews consume approximately 40 percent more food in winter than in summer (Randolph, 1973). Short-tailed shrews' digestive efficiency is about 90 percent (Randolph, 1973).

Shrews are an important component of the diet of many owls (Palmer and Fowler, 1975; Burt and Grossenheider, 1980) and are also prey for other raptors, fox, weasels, and other carnivorous mammals (Buckner, 1966).

TABLE 3-6
Diet Composition of Short-Tailed Shrews, *Blarina brevicauda*

Location	Prey Taxon	Percent	Comments	Reference
New York	earthworms	31.4	% volume stomach contents	Whitaker & Ferraro, 1963
	slugs and snails	27.1		
	misc. animals	8.1		
	Endegon (fungi)	7.7		
	beetles	5.9	June -October Collections Combined	
	vegetation	5.4		
	lepidopteran larva	4.3		
	chilopoda	1.8		
	other	8.6		
Eastern United States	insects	77.6	% frequency of occurrence; stomach contents	Hamilton, 1941
	annelids	41.8		
	vegetation	17.1		
	centipedes	7.4		
	arachnids	6.1		
	snails	5.4	all seasons combined	
	small mammals	5.2		
	crustacea	3.7		
	undetermined	2.4		

Food Consumption Rate

In laboratory studies shrews of both sexes fed a diet of mealworms (estimated 2.33 Kcal/g live weight) at temperatures between 22 and 23 °C had a food ingestion rate of 7.95 $\pm$ 0.17 g/d (0.47 g/g-day at a body weight of 16.8 g) (Barrett and Stuek, 1976). Lab studies using beef liver found that shrews (average body weight 21 g) had food ingestion rates between 0.49 g/g-day and 0.62 g/g-day at 25 °C (Morrison et al., 1957). Using Eq. 5 and a mean body weight of 0.0168 kg (calculated from above table using adults) a food consumption rate of 0.142 kg/kg BW/day DW can be estimated. Assuming a diet of 62.8 percent earthworms including slugs, snails and larvae, 32.5 percent insects such as beetles, chilopoda and others, and 4.7 percent vegetation (Whitaker and Ferraro, 1963) with respective water contents of 84, 61, and 85 percent (Table 3-4), a fresh weight of 0.72 kg/kg BW/day can be estimated using Eq. 18. (Note: if using different body weights, rate should be recalculated).

Water Consumption Rate

The shrew must consume water to compensate for its high evaporative water loss, despite the fact that it obtains water from both food and metabolic oxidation (Chew, 1951). Deavers and Hudson (1981) indicated that the short-tailed shrew's evaporative water loss increases with increasing ambient temperature even within its thermoneutral zone. Laboratory studies found water ingestion rates of 0.223 g/g-day (Chew, 1951). Using Eq. 19 and assuming a mean body weight of 0.0168 kg, a water consumption rate of 0.15 L/kg BW/day can be estimated. (Note: if using different body weights, rate should be recalculated).

Soil Ingestion

Data concerning soil ingestion by short-tailed shrews was not located in the literature. Beyer et al. (1994), however, reports soil ingestion by meadow voles to be 2.4 percent of the diet. Soil ingestion by pine voles is likely to be comparable or higher because of the greater fossorial nature of pine voles.

Respiration Rate

No literature data were found describing inhalation by short-tailed shrews. Using Eq. 21 and assuming a body weight of 16.8 g, the average inhalation rate is estimated to be 1.24 m^3 air/kg BW/day. (Note: If other body weight values are used, then the inhalation rate should be recalculated.)

Metabolism

Short-tailed shrews are active for about 16 percent of each 24-hour period (Martinsen, 1969), in periods of around 4.5 minutes at a time (Buckner, 1964). The shrew's metabolism is inversely proportional to the ambient temperature, within the range of 0 to 25° C (Randolph, 1973). Sleeping metabolism is half that associated with normal, exploring activity (Randolph, 1973). Randolph (1973) developed a regression equation for metabolism (cc O_2/g-hour) during (1) interrupted sleep:

$$\text{(Winter) } Y = 4.754 - 0.0869\,(X - 16.4305)$$

$$\text{(Summer) } Y = 5.3448 - 0.1732\,(X - 16.2310)$$

and (2) normal exploring activity:

(Winter) $Y = 6.5425 - 0.0516 (X - 12.0600)$

(Summer) $Y = 7.949 - 0.2364 (X - 16.9554)$, where X= ambient temperature in °C.

Randolph (1973) also developed a regression equation for overall metabolism (cal/animal-hour) for shrews spending equal amounts of time sleeping and exploring (cal/animal-hour) as a function of ambient temperature:

(Winter) $Y = 583.83 - 7.53 (X - 13.68)$

(Summer) $Y = 544.86 - 20.37 (X - 16.33)$, where X= ambient temperature in °C.

Deavers and Hudson (1981) found a linear increase in standard (near basal) metabolism with decreasing temperature that is similar to that for interrupted sleep described above (Y = standard metabolism in cc O_2/g-hour):

$Y = 8.84 - 0.22 (X)$, where X= ambient temperature.

Deavers and Hudson (1981) found that within the thermoneutral zone, the standardmetabolic rate of the short-tailed shrew is approximately 190 percent the metabolic rate predicted from body weight.

Habitat Requirements

Short-tailed shrews are found in a wide variety of habitats and are common in areas with abundant vegetative cover (Miller and Getz, 1977). They inhabit round, underground nests and maintain underground runaways, usually in the top 10 cm of soil, but sometimes as deep as 50 cm (Hamilton, 1931; and Jameson, 1943, cited in George et al., 1986). Short-tailed shrews need cool, moist habitats because of their high metabolic and water-loss rates (Randolph, 1973).

Home Range

Winter, nonbreeding home ranges can vary from 0.03 to 0.07 ha at high prey densities, to 1 to 2.2 ha during low prey densities, with a minimum of territory overlap. In the summer, ranges of opposite sex animals overlap, but same sex individuals do not; females with young exclude all others from their area (Platt, 1976). Short-tailed shrews inhabiting bluegrass areas of southern Michigan had summer home ranges of <0.1 to 0.36 ha for females and <0.1 to 1.8 ha for males (Blair, 1940). In another study, breeding individuals of both sexes living in tamarack bogs of south Manitoba had a mean (±SD) home range size of 0.39 ± 0.036 ha (Buckner, 1966).

Population Density

Population densities vary by habitat and season (Getz, 1989; Jackson, 1961; Platt, 1968). In East-central Illinois, population density was higher in bluegrass than in tallgrass or alfalfa (Getz, 1989). In all three of these habitats, the short-tailed shrew exhibited annual abundance cycles, with peak densities ranging from 2. 5 to 45 shrews per hectare, depending on the habitat (Getz, 1989). The peaks occurred from July to October (12.9/ha average for all three habitats), apparently just following peak precipitation levels (Getz, 1989). Winter, spring, summer and fall densities of 2.3, 5.9, 11.4, and 10.0 shrews/ha were reported from these Illinois alfalfa fields (Getz 1989). In a Wisconsin beech-maple forest, short-tailed shrew densities ranged from 1.6 to 121 shrews/ha (Jackson, 1961, Williams, 1936), whereas only 0.06 to 0.16 shrews/ha were observed in Manitoba tamarack bogs (Buckner, 1966).

Population Dynamics/Survival

Winter mortality up to 90 percent has been reported for the short-tailed shrew (Barbehenn, 1958; Gottschang, 1965; Jackson, 1961, cited in George et al., 1986); however, Buckner (1966) suggests that mortality rates in winter may be closer to 70 percent, which is similar to the average monthly mortality rate he found for subadult animals. Several litters, averaging four to five pups, are born each year (George et al., 1986). Life spans up to 20 months have been reported in short-tailed shrews studied in woods and fields or central New York (Dapson, 1968), while those in a Maryland lab have only survived for 4.6 (males) or 4.4 (females) months (Blus, 1971).

Reproduction/Breeding

The short-tailed shrew probably breeds all year, including limited breeding in winter even in the northern portions of its range (Blus, 1971). In Illinois, males were found to be most active from January to July, females from March to September (Getz, 1989). There are two peak breeding periods, in the spring and in late summer or early fall (Blair, 1940). Mating in Indiana begins in late February, peaking in April and May and ends in mid-September (French, 1984).

Behavior and Social Organization

The home ranges of short-tailed shrews in summer overlap both within and between sexes (Blair, 1940), although females with young do exhibit some territoriality (Platt, 1976). Nomadic shrews are either young of the year or adults moving to areas with more abundant prey (Platt, 1976).

3.2.2 Desert Shrew *(Nitiosorex crawfordi)*

The desert shrew is in the order Insectivora, family Soricidae. Until recently, it was the only species in the genus Nitiosorex, however, taxonomic studies have elevated the subspecies *N. c. evotis* to the species level. Additionally, a new species has been described from Tamaulipas, Mexico, *N. villai* (Carraway and Timm, 2000). The desert shrew has highly efficient kidneys and a lower metabolic rate relative to other shrews, and as such is able to inhabit more arid regions.

Distribution

The desert shrew has a wide distribution throughout the southwest and the southcentral United States extending into northern and central Mexico. It occurs in a wide variety of habitats from sea level to elevations as high as 2618 m (Davis and Sidner, 1989).

Body Size and Weight

The desert shrew is a small shrew with a long tail and conspicuous ears. The average total length is 81 mm with the head and body between 51 and 66 mm and the tail length from 24 to 29 mm. The average weight is 4 g with a range from 3.5 to 4.5 g for adults. The body weights for nestlings in Oklahoma ranged from 1.6 to 2.0 g (Preston and Martin, 1963) and neonates weigh 0.25 g (Hoffmeister, 1986).

TABLE 3-7
Body Weights (g) for the Desert Shrew, *Nitiosorex crawfordi.*

Location	Sex	N	Mean	Reference
San Diego Co., California	Female	1	3.3	Dixon, 1924
	Male	1	3.0	
Arizona	Male (12 months)	1	6	Hoffmeister and Woodrow, 1963
	Female (50-90 days)	1	3.4	

Food Habits and Diet Composition

Desert shrews are carnivorous, primarily insectivorous, but are nonselective in their diets. Common prey items include ground dwelling invertebrates such as crickets, cockroaches, grasshoppers, earwigs, and beetles as well as meal worms and cut worms. Occasionally they will eat centipedes and carrion such as dead birds, mammals, and reptiles, but will not eat live rodents (Armstrong and Jones, 1972). Insects are often paralyzed by crushing the head and then cached and eaten at a later time (Lindstedt and Jones, 1980).

Food Consumption Rate

Dixon (1924) reported that a captive desert shrew consumed 2.3 g of food per day. Desert shrews generally consume 75 percent or more of their body weight each day, and may consume food exceeding their own weight in a 24-hour period (Findley, 1987). Using Eq. 5 and assuming a mean body weight of 0.004 kg (Preston and Martin, 1963), a food consumption rate of 0.18 kg/kg BW/day can be estimated. A fresh weight of 0.58 kg/kg BW/day can be calculated assuming a diet of 100 percent terrestrial invertebrates with a water content of 69 percent (Table 3-4). (Note: if using different body weights, then the rates should be recalculated).

Water Consumption Rate

Desert Shrews have extremely efficient kidneys relative to other shrews and a permanent source of water does not appear to be required. Where water is not available, the desert shrew appears to be able to obtain sufficient water for survival from its' food sources (Ingles, 1965; Armstrong and Jones, 1972). If water is available, however, desert shrews will readily drink and are often found in the vicinity of a water source. Dixon (1924) describes the drinking behavior of a captive shrew supplied with water this way; "On one occasion the shrew drank eleven times in five minutes, lapping the water with the dainty tongue from five to twenty times at each drink". Using Eq. 19 and a body weight of 0.004 kg, a rate of 0.17 L/kg BW/day can be calculated. (Note: if using different body weights, then the rates should be recalculated)

Soil Ingestion Rate

There was no data found in the literature concerning soil consumption rates for desert shrews. However, Talmage and Walton (1993) reported a soil ingestion rate of 13 percent of the diet for short-tailed shrews and it is likely that desert shrews have a similar rate.

Respiration Rates

Dixon (1924) reported that a desert shrew in captivity had "seventy respirations" in thirty seconds. Using Eq. 21 and a mean body weight of 0.004 kg, a rate of 1.65 m^3/kg BW/day can be estimated. (Note: if using different body weights, then the rates should be recalculated).

Metabolism

Lindstedt (1980) determined the basal metabolic rate (BMR) of the desert shrew to be 3.27 mL O_2/g/h at a temperature of 37.6 °C. Desert shrews also appear to go into daily torpor during the hottest part of the day both to save energy as well as conserve water loss (Genoud, 1988).

Habitat Requirements

The common name desert shrew is a bit misleading, as this species occurs in a wide variety of habitat types and is more properly referred to as the gray shrew (Carraway and Timm, 2000). Habitat types include desert scrub, yellow pine forests, pine-oak forests, oak chaparral, oak woodlands, riparian woodlands, alkaline marsh, sandy flats, and arid grasslands (Carraway and Timm, 2000; Armstrong and Jones, 1972, Ingles, 1965). A permanent source is not required, however, sheltered microhabitats are important in habitat suitability. Dense vegetation, logs, rocks, brush, and rubbish are frequently used for cover. Desert shrews have also been found in abandoned beehives and frequently associate with woodrats (*Neotoma* spp.) in both active and abandoned dens (Armstrong and Jones, 1972).

Home Range

Most studies on desert shrews are from captive populations and no published information was found regarding the home range of desert shrews in the wild. Using Eq. 28 and a mean body weight of 3.93 g (calculated mean from weights of adults in Table 3-7) the estimated home range size of desert shrews is 0.71 ha. In contrast, the home range size estimate for desert shrews is only 0.08 and 0.10 ha using Eq. 23 and 24, respectively.

Population Density

Preston and Martin (1963) estimated the population density in Oklahoma to be 6.4 desert shrews per ha in a mesquite-mixed grassland-prickly pear habitat. While they are found in a variety of habitats, the particular type of habitat seems to have an impact on relative abundance of desert shrews. In Arizona cottonwood-willow riparian areas, followed by saltcedar and sacaton-mesquite associations had the highest relative abundance where grassland-white thorn and tarbush-white thorn habitats had the lowest relative abundance (Duncan and Corman, 1991). Simons et al. (1990) found similar results with three times as many shrews captured in riparian areas than in upland habitats in southern Arizona. Thus it seems that while desert shrews are capable of inhabiting xeric habitats, more mesic sites support greater population densities.

Population Dynamics/Survival

No information was found on population dynamics or survival of desert shrews. However, the only documented predators of desert shrews are great-horned owls and barn owls (Armstrong and Jones, 1972). Captive shrews have been reported to live up to 40 weeks without water, but with an adequate food supply (Hoffmeister, 1986).

Reproduction and Breeding

Hoffmeister (1986) suggests that desert shrews breed throughout the year, however, the peak breeding season likely occurs during the warmer summer months, April through September (Armstrong and Jones, 1972). Simons et al. (1990) found that young were more prevalent in the summer than in the spring. Both sexes contribute to nest construction. A typical litter includes 3-5 young that are weaned and leave the nest in 40 days (Armstrong and Jones, 1972).

Behavior and Social Organization

Desert shrews are active year-round and are primarily nocturnal, often spending the hottest part of the day in torpor. Unlike other shrews, the desert shrew is non-fossorial, but may dig through sand in search of food. Their movements are rapid and nervous. They do not develop runways around nest-sites like many shrews, but will use paths created by other small mammals. Desert shrews are not social, and are generally solitary with the exception of mating; however, captive populations showed little antagonism among individuals if food was available (Hoffmeister and Goodpaster, 1962). They are often found in association with other rodents such as woodrats (Armstrong and Jones, 1972).

3.2.3 Big Brown Bat (*Eptesicus fuscus*)[3]

Big brown bats are in the order Chiroptera, family Vespertilionidae. There are 11 subspecies of *Episticus* and the big brown bat is the only North America representative of the genus (Kurta and Baker, 1990). They live in a wide variety of habitats and are only absent from the highest alpine meadows and talus slopes, but are not common in deserts (Zeiner et al., 1990). They are uncommon in desert environments where they are often restricted to forested highlands (Kurta and Baker, 1990). Big brown bats are insectivores that occasionally feed from the ground (Zeiner et al., 1990).

Distribution

Eptisticus fuscus range from northern South America to southern Canada and Alaska and are found throughout the United States except Hawaii (Kurta and Baker, 1990). *E. fuscus* also inhabit many Caribbean Islands and are relatively abundant over their entire range (Harvey, 1992). Studies of big brown bats have been conducted in Arizona (Fenton and Morris, 1976), Massachusetts (Gould, 1955), Oregon, and Mexico (Griffith and Gates, 1984). The winter location of most *E. fuscus* colonies is unknown (Harvey, 1992).

Body Size and Weight

Female big brown bats are larger than males (see Table 3-8). The wingspread of females is much larger than that of males (Phillips, 1966).

Food Habits and Diet Composition

Big brown bats are opportunistic and use ultrasonic sound to detect their prey (Fenton and Morris, 1976). They are dietary specialists, preferring Coleoptera, Hemiptera, Homoptera, and Neuroptera species (Griffith and Gates, 1984). Small Coleoptera were the most common prey found in a study by Kurta and Baker (1990). Phillips (1966) observed 80 percent of the volume of food in the bat stomachs he studied was Coleoptera. Only small amounts of moths have been

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[3] New species accounts compiled for ARAMS.

TABLE 3-8
Body Weights (kg) for the Big Brown Bat, *Eptesicus Fuscus*

Location	Sex	N	Mean	Reference
Manitoba	Male		0.0209	Buckner, 1961*
Ontario	Both		0.02 to 0.025	Hitchcok et al., 1984*
Canada	Both		0.0179±0.0057	Van Zyll de Jong, 1985*
Alberta	Both		0.015 to 0.019	Soper, 1973*
France	Male		0.0172	Saint-Girons et al., 1969*
	Female		0.0188	
Chihauha	Both		0.0123±0.002	Anderson, 1972*
Cuenca de Mexico	Both		0.011 to 0.017	Ceballos Gonzalez and Leal, 1984
Guerrero, MEX	Both		0.0188	Lukens and Davis, 1957*
N neotropics	Female		0.00263	Eisenberg, 1989*
Arkansas	Female		0.0169	Sealander, 1979*
	Male		0.0137	
	Both		0.01 to 0.033	
Indiana	Female		0.021 to 0.0265	Mumford and Whitaker, 1982*
	Male		0.012 to 0.0206	
	Male		0.0138	Lindsay, 1956*
	Female		0.0189	
	Male		0.0129 to 0.0224	Mumford, 1958*
	Female		0.0148 to 0.0253	
Kentucky	Female		0.016	Davis et al., 1968*
Massachusetts	Both	1	0.0189	Gould, 1955*
	Both-young	11	0.0091	Gould, 1955
Minnesota	Female		0.022	Goehring, 1972*
	Male		0.0192	
Texas	Female		0.0205	Kuntz, 1974*

*In CRC Handbook of Mammalian Body Masses (Silva and Downing, 1995)

found in the stomachs of big brown bats (Black, 1972). Stomach contents, in a study by Kurta and Baker (1990), were found to be 4 percent vegetation and nonflying insects. The most common prey of big brown bats studied in Indiana were Carabidae (ground beetle), Scarabaeidae (June beetle), and Chrysomelidae (cucumber beetle; Whitaker, 1972). Brigham and Saunders (1990) used traps to determine the availability of invertebrates on the same nights they captured individual bats for stomach examination. Although only 1.9 percent of invertebrates caught in traps were Coleopteran, 54.5 percent of the food volume in stomachs of the bats that were examined was Coleopteran.

Brigham (1990), studying big brown bats in British Columbia, found the dominant prey species to be Trichopterans. In another study, Brigham and Saunders (1990) found Coleoptera to be the dominant prey species in southern Alberta.

TABLE 3-9
Diet Composition for the Big Brown Bat, *Eptesicus Fuscus.*

Location	N	Prey Taxon	Percent Volume	Percent Frequency	Reference
Eastern Oregon	60	Lepidoptera	13.8	30.0	Whitaker et al., 1981
		Isoptera	0.3	3.3	
		Muscoidea	0.2	1.7	
		Unidentified Diptera	1.5	15.0	
		Formicidae	9.2	18.3	
		Pentatomidae	1.0	8.3	
		Lygaeidae	2.9	21.7	
		Neididae	0.2	1.7	
		Miridae	0.3	1.7	
		Unidentified Hemiptera	1.9	13.3	
		Gryllidae	0.3	1.7	
		Unidentified Orthoptera	0.6	3.3	
		Scarabaidae	22.7	40.0	
		Caribidae	11.9	18.3	
		Cerambycidae	2.3	11.7	
		Chrysomelidae	2.5	5.0	
		Coleoptera	13.2	35	
		Cicadelliadae	0.3	8.3	
		Cercopidae	9.9	21.7	
		Araneida	0.1	1.7	
		Hemerobildae	1.3	11.7	
		Unidentified insects	2.8	20.0	
		Phalangida	0.3	1.7	
Indiana	184	Carabidae	14.6	29.8	Whitaker, 1972
		Scarabaeidae	12.4	25.0	
		Chrysomelidae	11.5	21.7	
		Pentatomidae	9.5	29.3	
		Formicidae	8.5	16.8	
		Coleoptera	6.6	15.2	

TABLE 3-9
Diet Composition for the Big Brown Bat, *Eptesicus Fuscus.*

Location	N	Prey Taxon	Percent Volume	Percent Frequency	Reference
		Ichneumonidae	5.0	14.1	
		Lepidoptera	4.5	7.6	
		Cicadellidae	4.4	20.7	
		Unidentified Insects	3.1	11.4	
		Chrysomelidae	3.0	9.8	
		Gryllidae	3.0	9.2	
		Diptera	1.8	7.1	
		Reduviidae	1.8	7.6	
		Internal organs of insects	1.5	2.2	
		Trichoptera	1.4	3.3	
		Vegetation	1.1	1.6	
		Other invertebrates	5.5	22.4	
Kansas	10	Coleoptera	80	100	Phillips, 1996
		Hemiptera	18	100	
		Diptera	<2	30	
		Hymenoptera	<2	40	
		Homoptera	<2	20	
		Lepidoptera	<2	10	
Southern Alberta	14	Lepidoptera	24.1	15.1	Brigham and Saunders, 1990
		Coleoptera	54.5	66.6	
		Hemiptera	28.9	22.1	
		Diptera	14.8	7.7	
		Trichoptera	1.5	0.2	
		Other	3.0	0.4	

Food Consumption Rate

Fenton and Glen (1973) studied captive *E. fuscus* fed beetles and *Tenebrio moliter* and found post-lactating females ingested 0.24 g/g BW/day. In the wild, young *Episticus* with an average body mass of 9.1 g consumed 1.1 g/h in Massachusetts and an adult specimen weighing 18.9 g consumed 2.7 g/h (Gould, 1955). An 18.9 g *Episticus* consumed 4 g in 1.5 hours (Gould, 1953). Using Eq. 5 and assuming a mean body weight of 0.018 kg (as calculated using above body weight table and adults) a food consumption rate of 0.14 kg/kg BW/day can be calculated. A fresh weight food consumption rate of 0.36 kg/kg BW/day can be calculated assuming a diet of 100 percent terrestrial insects with a water content of 61 percent (Table 3-4) (Note: if using different body weights, then the rates should be recalculated).

Water Consumption Rate

Both male and female big brown bats consumed 0.64 mL of water per week per g body weight (0.09 L/kg BW/day) in a study of captive big brown bats (Coutts et al., 1973). For comparison, a water consumption rate of 0.15 L/kg BW/day can be estimated using Eq. 19 and assuming a mean body weight of 0.018 kg (Note: if using different body weights, then the rates should be recalculated).

Soil Ingestion

No published data were found concerning soil ingestion by big brown bats; however, studies of food habits (Whitaker, 1972; Whitaker et al., 1981; Griffith and Gates, 1985) do not indicate soil in the diet. Additionally, the big brown bat is an aerial insectivore, therefore soil ingestion is assumed to be negligible.

Respiration Rate

Active bats consume 0.8 mL/g BW/h of oxygen at 35 °C (Kurta and Baker, 1990). Thomas and Suthers (1972) measured oxygen consumption during flight of *Phyllostomas hastatus,* weighing between 70 and 110 g, and found that mean oxygen consumption varied from 24.68 mL/g BW/h to 27.53 mL/g BW/h depending on flight speed. An estimate of 1.22 m^3/kg BW/day can be calculated using Eq. 21 and a mean body weight of 0.018 kg. (Note: if using different body weights, then the rate should be recalculated).

Metabolism

Metabolic data for active *E. fuscus* (Kurta and Baker, 1990) and flying *P. hastatus* (Thomas and Suthers, 1972) were available and are described above. Although no information on energy requirements is presented in the literature, the field metabolic rate for big brown bats can be calculated for chiropterans using the allometric presented in Nagy et al. (1999). Using a mean body weight of 0.18 kg, the field metabolic rate for big brown bats is 46.5 kJ/day.

Habitat Requirements

Big brown bats have night and day roosts (Kurta and Baker, 1990) as well as summer and winter roosts. Summer roosts are in attics, barns, and other man-made structures; winter roosts are in caves, mines, and other underground structures (Harvey, 1992). Big brown bats cannot live in an environment where the temperature exceeds 33 °C (92^0 F) (Zeiner et al., 1990) and will leave roosts and move to a new location if conditions are not suitable (Kurta and Baker, 1990). Winter roosts are used for hibernation. They awaken from hibernation when the temperature drops below 0 °C (32 °F) and move to a warmer location (Zeiner et al., 1990). The average period of hibernation is 7 to 25 days in Missouri, but can extend to 72 days (Brack and Twente, 1985). The length of hibernation is affected by temperature, the lower the temperature the longer a bat will remain in hibernation (Twente et al., 1985). The frequency of arousal is controlled metabolically (Twente et al., 1985). Most big brown bats hibernate singly, but sometimes will form groups of two to eight bats (Brack and Twente, 1985). In Missouri, big brown bats roosting in a mine did not share roosts with other bat species (Phillips, 1996). Trees and rock crevices are also used for roosting (Kurta and Baker, 1990). Big Brown bats forage over open areas and water bodies, using the same routes. (Zeiner, 1990).

Home Range

Home ranges of 111 km^2 (43 mi^2 or 11,100 ha) have been estimated with a decreasing ability to home as distance increases (Zeiner et al., 1990). Big brown bats are territorial and several days pass before a new bat will replace a bat missing from a territory (Zeiner et al., 1990). In a study by Kurta and Baker (1990), the distance between roost and forage grounds was 1-2 km.

Population Density

Big brown bats form maternal colonies numbering between 10 and 300 individuals and will roost with other bat species (Zeiner et al., 1990). Big brown bats hibernate alone or in small clusters with the average number of bats being 3.7 (Phillips, 1996). Adult males may be found with maternal colonies, in all male colonies, or remain solitary (Kurta and Baker, 1990).

Population Dynamics/Survival

The mean annual survival rate of adults ranges from 10-77 percent. The mortality rate has been estimated as 40percent (Phillips, 1996). The average age within a population is 2-3 years, but the maximum recorded age is 19 years (Zeiner et al., 1990). Males generally live longer than females (Kurta and Baker, 1990). Mortality before weaning was 7-10 percent (Kurta and Baker, 1990). Owls, snakes, and hawks are common predators of big brown bats (Zeiner et al., 1990). Other predators are common grackles, American kestrels, long-tailed weasels, rats, and house cats (Kurta and Baker, 1990).

Reproduction/Breeding

Breeding occurs in the fall, but can extend to March (Zeiner et al., 1990). Fertilization is delayed until bats emerge from hibernation and the gestation period is 60 days (Kurta and Baker, 1990). In southern California, young are born between May and July with a yearly litter range of 1-5 young (Zeiner et al., 1990). In the Great Plains, there are usually two young and west of the Great Plains there is typically only one young born (Phillips, 1996). Females have been found lactating between May and August (Zeiner et al., 1990). Reproduction begins in the first or second year with younger bats having higher mortality and a lower pregnancy rate than older bats (Zeiner et al., 1990). Juveniles begin to fly when they are between 18 and 35 days old (Kurta and Baker, 1990).

Behavior and Social Organization

Big brown bats are nocturnal with peak activity usually occurring 1-2 hours after sunset (Zeiner et al., 1990). In Michigan, foraging began 18 minutes after sunset and in Kansas foraging began 49 minutes after sunset (Kurta and Baker, 1990). Chronic disturbance will force them to vacate their roost (Zeiner et al, 1990). Geggie and Fenton (1985) observed that bats preferred rural foraging to urban foraging, shunning parkland and farmland. Bats preferred residential and over the water flying zones.

When disturbed big brown bats will become excited and may attack one another. Phillips (1996) observed this behavior in a cave during the winter months when bats were disturbed from hibernating.

3.2.4 Little Brown Bat (*Myotis lucifugus*)[2]

Little brown bats are in the order Chiroptera, family Vespertilionidae. The genus *Myotis* includes approximately 80 species; *M. lucifugus* includes six subspecies (Fenton and Barclay 1980). As with most vespertilionids, the little brown bat is strictly insectivorous (Vaughan, 1978).

Distribution

The little brown bat is one of the most abundant bats throughout the northern United States and Canada (Harvey, 1992). It is widely distributed throughout North America. Its range extends from east to west coasts and from the mountains of northern Mexico to Alaska (Burt and Grossenheider, 1976; Fenton and Barclay, 1980).

Body Size and Weight

Female little brown bats are somewhat larger than males (Fenton and Barclay, 1980). Reported body mass may range from 3.1 to 12 g (Silva and Downing, 1995) but averages 7 to 9 g (Burt and Grossenheider, 1976). Body weight varies throughout the year, remaining relatively constant from March through August then increasing dramatically in September through October, prior to hibernation (LaVal et al., 1977). Body weights for little brown bats from several locations are presented in Table 3-10. Additional data on body weights are reported in Silva and Downing (1995).

TABLE 3-10
Body Weights (g) for the Little Brown Bat, *Myotis lucifugus*

Location	Sex	N	Mean	Range	Comments	Reference
Massachusetts	not stated	4	7.5±1.1[a]			Gould, 1955
New Mexico	Female (ad)[b]	5	8.47±0.81	7.25-9.43	Collected 19 Aug.; data also presented for 1 and 15 Sept.	Ewing et al. 1970
	Male (ad)	3	6.96±0.27	6.57-7.20		
	Female (yy)[c]	4	6.78±0.21	6.61-7.14		
	Male (yy)	2	5.74±0.06	5.69-5.80		
Alberta, Canada	not stated		10.3	7.4-11.6		Silva and Downing, 1995
Indiana	Male	6	6.03			Stones and Wieber, 1965
	Female: nonpregnant, nonlactating	40	6.99			
	Female: pregnant	6	10.27			
	Female: lactating	13	7.77			

[a] mean±standard deviation
[b] adult
[c] young of year

Food Habits and Diet Composition

Little brown bats are strict insectivores, detecting insects using ultrasonic calls (Fenton and Barclay, 1980). Although insects are generally captured in flight, some may be taken from the surface of water or vegetation (Fenton and Bell, 1979). Foraging is opportunistic; little brown bats have been observed to exploit insect swarms attracted to artificial lights

2 Text directly from Sample et al. (1997a).

(Fenton and Morris, 1976) or large insect hatches (Vaughan, 1980). While the diet composition may be highly variable, aquatic insects (e.g., Chironomidae and Trichoptera) are the primary food in most areas studied (Table 11; Fenton and Barclay, 1980; Anthony and Kunz, 1977; LaVal et al., 1980). However, in Alaska the diet consisted primarily (71.1 percent by volume) of small moths (Whitaker and Lawhead, 1992). Insects consumed generally range from 3 to 10 mm in size (Anthony and Kunz, 1977). Additional data concerning diet preferences of little brown bats may be found in Barclay (1991), Belwood and Fenton (1976), Kunz and Whitaker (1983), and Whitaker et al. (1981).

TABLE 3-11
Diet Composition of Little Brown Bats, *Myotis lucifugus*

Location	Prey Taxon	Percent Volume	Percent Frequency	Reference
Western Oregon	Chironomidae	38.4	62.7	Whitaker et al., 1977
(n=67)	Unidentified Diptera	10.4	28.4	
	Tipulidae	2.4	7.5	
	Culicidae	0.4	1.5	
	Dipterous larvae	0.1	1.5	
	Insect internal organs	10.6	11.9	
	Isoptera	8.9	13.4	
	Trichoptera	8.4	10.4	
	Unidentified insects	6.3	26.9	
	Unidentified Lepidoptera	3.7	10.4	
	Lepidopterous larvae	1.4	1.5	
	Formicidae	2.3	6.0	
	Unidentified Hymenoptera	0.4	1.5	
	Scarabidae	1.5	1.5	
	Unidentified Coleoptera	0.4	3.0	
	Unidentified Hemiptera	1.5	3.0	
	Cercopidae	1.0	1.5	
	Cicadellidae	0.4	3.0	
	Unidentified Homoptera	0.4	1.5	
	Tettigonidae	0.5	1.5	
	Gryllidae	0.1	1.5	
	Hemerobiidae	0.4	1.5	
Nova Scotia	Coleoptera	7.7		Belwood and Fenton, 1976
adults	Trichoptera	34.6		
(n=28)	Chironomidae	58.8		
	Other insects	3.8		

TABLE 3-11
Diet Composition of Little Brown Bats, *Myotis lucifugus*

Location	Prey Taxon	Percent Volume	Percent Frequency	Reference
Nova Scotia subadults (n=27)	Coleoptera	9.4		Belwood and Fenton, 1976
	Trichoptera	26.6		
	Lepidoptera	15.9		
	Neuroptera	11.6		
	Chironomidae	19.5		
	Other Diptera	7.7		
	Other insects	9.2		
Watertown, New York; adults (n=12)	Coleoptera	1.2		Belwood and Fenton, 1976
	Trichoptera	18.2		
	Lepidoptera	4.2		
	Chironomidae	76.4		
Watertown, New York; subadults (n=12)	Coleoptera	6.6		Belwood and Fenton, 1976
	Trichoptera	29.6		
	Lepidoptera	19.9		
	Neuroptera	3.5		
	Chironomidae	35.5		
	Other insects	4.9		
Western Maryland (n=33)	Coleoptera		63.6	Griffith and Gates, 1985
	Diptera		54.5	
	Hemiptera		3.0	
	Homoptera		36.4	
	Hymenoptera		39.4	
	Lepidoptera		60.6	
	Neuroptera		24.2	
	Psocoptera		15.2	
	Trichoptera		15.2	
New Hampshire (n=62) (Paper provides additional breakdown by sex, date, and age)	Chironomidae		85.5	Anthony and Kunz, 1977
	Lepidoptera		85.5	
	Culicidae		77.4	
	Tipulidae		67.7	
	Coleoptera		59.7	
	Mycetophilidae		54.8	
	Ephemeroptera		51.6	
	Hymenoptera		33.9	

TABLE 3-11
Diet Composition of Little Brown Bats, *Myotis lucifugus*

Location	Prey Taxon	Percent Volume	Percent Frequency	Reference
	Trichoptera		32.3	
	Neuroptera		19.4	
Indiana	Unidentified Lepidoptera	21.6	31.3	
(n=16)	Unidentified Trichoptera	13.1	25.0	Whitaker, 1972
	Unidentified Diptera	11.9	31.3	
	Cicadellidae	11.6	43.8	
	Delphacidae	8.8	25.0	
	Coleopterous larvae	6.3	6.3	
	Ichneumonidae	3.8	12.5	
	Carabidae	3.4	18.8	
	Reduviidae	2.8	12.5	
	Scarabidae	2.5	6.3	
	Unidentified Coleoptera	2.2	18.8	
	Tipulidae	1.9	12.5	
	Hemerobiidae	1.9	6.3	
	Chironomidae	1.6	12.5	
	Cerambycidae	1.6	6.3	
	Formicidae	1.3	12.5	
	Chrysomelidae	0.9	6.3	
	Chrysomelidae, *Diabrotica sp.*	0.9	6.3	
	Nitidulidae	0.9	6.3	
	Miridae	0.6	6.3	
	Gryllidae	0.3	6.3	
	Unidentified insects	0.3	6.3	

Food Consumption Rate

Little brown bats maintained in captivity (at 92°F) and fed mealworms consumed 1 to 4 g food/d, with the greatest consumption observed for pregnant and lactating females (Stones and Wiebers, 1965). Food consumption was also greater in summer as opposed to winter. Coutts et al. (1973) observed an average food consumption rate of 0.15 g/g/d for three males and six postlactating females. Feeding rates for bats in the field are likely to be higher. For example, Gould (1955) reports food consumption rates for four "more successful" bats to be 7.7±2.6 g/g/h (mean±STD). If 3.5 h/d are spent foraging (Anthony and Kunz, 1977), this would translate to a daily consumption rate of 1.12±0.37 g/g/d. This is consistent with Barclay et al.

(1991) who suggest that bats may consume their body weight in food per night to meet metabolic needs. Anthony and Kunz (1977) reported daily food consumption rates in New Hampshire to be 2.4±1.1 g/d (mean±STD), 3.7±0.5 g/d, and 1.8±0.5 g/d, for pregnant, lactating, and juvenile little brown bats, respectively. Assuming body weights reported in Table 3-10, these observations translate to 0.23±0.11g/g/d, 0.48±0.06 g/g/d, and 0.29±0.07 g/g/d.

Water Consumption Rate

A single little brown bat maintained in the laboratory was observed to consume 0.86 mL of water per day (O'Farrell et al., 1971). The average weight of this individual over the course of the study was 7.89 g. Therefore the daily water consumption was 0.11 L/kg/d. In another laboratory study, average water consumption of male and female little brown bats maintained in the laboratory was observed to be 0.18 L/kg/d (Coutts et al., 1973). Kurta et al. (1989) estimated the drinking water consumption rate of free-ranging pregnant and lactating bats to be 0.177 L/kg/d and 0.205 L/kg/d, respectively. These observations are comparable to water ingestion estimated using Eq. 19. Assuming a body weight of 7.5 g, water ingestion by little brown bats is estimated to average 0.16 L/kg BW/d. (Note: If other body weight values are used, the water ingestion rate should be recalculated.)

Soil Ingestion Rate

No published data were found concerning soil ingestion by little brown bats. As an aerial insectivore, however, soil ingestion is assumed to be negligible.

Respiration Rate

No literature data were found describing inhalation by little brown bats. Using Eq. 21 and assuming a body weight of 7.5 g, the average inhalation rate of little brown bats is estimated to be 1.45 m^3/kg BW/d. If other body weight values are used, the inhalation rate should be recalculated.

Metabolism

Energy utilization by little brown bats is highly efficient. Of 4.15±0.67 kcal/d ingested, only 0.37±0.1 kcal/d was excreted, representing an energy utilization of 91.2±1.5 percent (O'Farrell et al., 1971). Metabolic rates for little brown bats have been reported to range from 1.47 mL O_2/g BW/h (O'Farrell and Studier, 1970) to 2.89±0.89 mL O_2/g BW/h (Altman and Dittmer, 1974). Little brown bats enter hibernation September-May in northern portions of their range and November-March in southern areas (Fenton and Barclay, 1980).

Habitat Requirements

Little brown bats use three distinct types of roosts: day, night, and hibernation. Day and night roosts are used by active bats in spring, summer, and fall, while hibernation roosts (hibernacula) are used during winter (Fenton and Barclay, 1980). Day roosts generally consist of dark or dimly lit locations (buildings, hollow trees, under bark, occasionally in caves) with the appropriate humidity and temperature to mitigate daytime water loss (Fenton and Barclay, 1980). Night roosts are occupied after the initial feeding bout of the evening. They may be located in the same building as day roosts but in different locations. Night roosts are generally confined spaces into which the bats pack themselves, possibly for improved thermoregulation (Fenton and Barclay, 1980). Hibernacula generally consist of caves or abandoned mines and are used throughout the bat's range. (Harvey et al., 1991) High humidity (>90 percent) and temperatures above freezing characterize most hibernacula (Fenton and Barclay, 1980).

Little brown bats forage primarily in open habitat, frequently over bodies of water (Fenton and Bell, 1979; Barclay, 1991; Saunders and Barclay, 1992). Areas with dense vegetation or other obstructions to flight are avoided (Barclay, 1991; Saunders and Barclay, 1992). In Missouri, foraging along forest edges has been observed (LaVal et al., 1977).

Home Range

Although no information was found in the literature concerning the home range of little brown bats, the gray bat, a congeneric species, may travel as far as 12 km from roost caves to foraging sites (LaVal et al., 1977).

Population Density

No data were found documenting population density values. Populations may be limited by the availability of roost sites but not by food (Fenton and Barclay, 1980). In summer, females form maternity colonies of hundreds to thousands of individuals (Harvey, 1992). Location of males in summer is not well known; it is suspected that they are solitary and scattered in a variety of roost types (Harvey, 1992).

Population Dynamics/Survival

Population age structures and survival rates for little brown bats are poorly defined (Fenton and Barclay, 1980). While individuals up to 30 years old have been reported (Keen and Hitchcock, 1980) and 10-year-old bats are not uncommon, longevity is generally 1.5 years for males and 1.17 to 2.15 years for females (Fenton and Barclay, 1980). Annual survival rates in Ontario were estimated to be 0.816 and 0.708 for males and females, respectively (Keen and Hitchcock, 1980). Cockrum (1956) presents additional data on longevity.

Reproduction and Breeding

Fertilization occurs in spring, after females leave hibernation. The gestation period is 50-60 days. Only one young is produced per year (Fenton and Barclay, 1980). Growth is rapid; young bats can thermoregulate by day 9.5 and are flying in three weeks. Buchler (1980) observed first flights of juveniles at 19-20 days of age. A detailed study of reproduction, growth, and development was performed by O'Farrell and Studier (1973).

Behavior

In New Hampshire, Anthony and Kunz (1977) observed bimodal foraging activity; the first feeding period was before midnight (2200-2400 h) while the second was before dawn (0330-0500 h). In contrast, Saunders and Barclay (1992) found activity was greatest within one hour of sunset.

3.2.5 Coyote (*Canis latrans*)[2]

Coyotes are in the order Carnivora, family Canidae. Coyotes are closely related to jackals, having 19 recognized subspecies (Bekoff, 1982). Coyotes tend to hunt prey alone or in pairs and are primarily carnivorous. They eat mostly small mammals but also birds, reptiles, insects, fruits, seeds, berries, and nuts (Bekoff, 1982).

Distribution

Coyotes are nearctic canids, occupying many diverse habitats, including grasslands, deserts and mountains, between about 10° north latitude and 70° north latitude (Bekoff, 1982). They are found throughout the continental United States and much of Canada; some use urban habitats. Coyotes have been extending their range in the past 40 years, possibly because of the extermination of the gray wolf and the destruction of wolf habitat (Thurber and Peterson, 1991).

Body Size and Weight

Coyotes range in length from about 1 to 1.5 m, with a tail about 400 mm long (Bekoff, 1982). Size and weight vary across different geographic locations and with different subspecies, although adult males tend to be slightly heavier and larger than adult females. The variation in body weights of male and female coyotes from different locations across North America are shown in Table 3-12. The birth weight of coyotes is about 240-275 g, with the body from head to tail measuring 160 mm (Bekoff, 1982).

TABLE 3-12
Body Weights (kg) for the Coyote (*Canis latrans)*

Location	Sex	N	Mean±SE	Range	Reference
Iowa	Male		13.4		Bekoff, 1982
	Female		11.4		
Minnesota	Male			12-13	Bekoff, 1982
	Female			11-12	
	Juvenile male			10-11	
	Juvenile female		10		
California	Male	28	11.2	8.2-12.5	Hawthorne, 1971
	Female	26	9.8	7.7-12.0	
Maine	Male	28	15.8±1.24		Richens and Hugie, 1974
	Female	20	13.7±1.24		
Kansas	Male		13.1		Bekoff, 1982
	Female		11.0		
Ontario	Both: 1959-1960	124	14.6±0.17		Schmitz and Lavigne, 1987
	Both: 1983-1984	44	15.5±0.37		
Alaska	Male	26	12.9±0.2		Thurber and Peterson, 1991
	Female	28	11.1±0.2		
Arizona	Both	18	10±0.04		Golightly and Ohmart, 1983
Oklahoma	Male	7	13.9	12-15.3	Halloran and Glass, 1959
Connecticut and Massachusetts	Male			11.7-15.9	Pringle, 1960
	Female			11.2-12.3	

[2] Text directly from Sample et al. (1997a).

Food Habits and Diet Composition

Coyotes are opportunistic foragers (Toweill and Anthony, 1988; Todd et al., 1981), consuming a wide variety of foods (Bowen, 1981). Coyotes have also been shown to follow a strategy of optimal foraging (MacCracken and Hansen, 1987). Coyotes are primarily carnivorous, feeding principally on birds and mammals, but also relying on insects and fruits (Fichter et al., 1955). Selected information on diet preferences of coyotes is presented in Table 3-13. The evidence from the studies on stomach and scat contents of coyotes indicates that there is a seasonal shift in food habits (Korschgen, 1957; Hawthorne, 1972; Bowen, 1981; MacCracken and Uresk, 1984; Smith, 1990). Only a small percentage of a coyote's diet is livestock; actual predation on livestock is rare (Bekoff, 1982; Wells and Bekoff, 1982).

TABLE 3-13
Diet Composition of Coyotes as Determined by Stomach Content Analysis, *Canis latrans*

	Percentage Volume						
Location	**Mammals**	**Birds**	**Insects**	**Plants**	**Carrion**	**Misc.**	**Reference**
12 Western states	64 (29% lagomorphs, 17% rodents, 14% livestock, 2% deer, 2% skunk and badger)	3	1	3	29		Sperry, 1933
10 Western states	60 (34% lagomorphs, 15% rodents, 8% livestock, 3% deer)	3		1	36		Sperry, 1934
Nebraska	78 (54% lagomorph, 12.5% livestock, 6.9% mice, 4.6% other)	17.7	0.9	1.6		1.8	Fichter et al., 1955
Missouri (spring)	77.1 (48.6% lagomorphs, 16.5% livestock, 5.4% mice and rats, 6.6% other)	17.7 (17% poultry)	tr.	0.2	5.0		Korschgen, 1957
Missouri (summer)	65 (35.2% lagomorphs, 17.5% livestock, 5.6% mice and rats, 6.7% other)	28 (27.4% poultry)	1.9	0.8	4.3		Korschgen, 1957
Missouri (fall)	72.2 (47.7% lagomorphs, 7.2% livestock,	13.2 (12.8% poultry)	3.5	6.5	4.3	0.3	Korschgen, 1957

TABLE 3-13
Diet Composition of Coyotes as Determined by Stomach Content Analysis, *Canis latrans*

Location	Percentage Volume						Reference
	Mammals	Birds	Insects	Plants	Carrion	Misc.	
	9% mice and rats, 8.3% other)						
Missouri (winter)	82.7 (58.1% lagomorphs, 7.6% livestock, 9.5% mice and rats, 7.5% other)	9 (8.5% poultry)	tr.	0.9	6.6	0.8	Korschgen, 1957

Food Consumption Rate

Fitch (1948) conducted a captive feeding study with one adult female coyote captured in the San Joaquin Experimental Range, California. Over a one-month period, the coyote consumed a daily average of 0.54 kg of food (body weight not reported). The author observed that the coyote would have eaten even more if given the opportunity and estimated the average food consumption under natural conditions to be about 1.5 lb/d (0.68 kg/d). Huegel and Rongstad (1985) observed food consumption rates of 10-12 percent of body mass/day among radio-tagged coyotes in northern Wisconsin in winter. Litvaitis and Mautz (1980) estimate the annual ingestion rates of deer, hares, and mice by a 12.9 kg eastern coyote to be 167 kg, 166 kg, and 134 kg, respectively. These values are equivalent to a daily consumption rate of 0.028 to 0.035 g/g/d. Golightly and Ohmart (1983) estimated the minimum energy requirements for desert coyote to be 260 J/g/d. Assuming a diet consisting of small mammals with a caloric density of 21.6 kJ/g (Golley, 1961) and a water content of 68 percent (Table 3-4), this is equivalent to daily consumption rate of 0.018 g/g/d.

Water Consumption Rate

No literature data were found describing water ingestion by coyotes. Using Eq. 19 and assuming a body weight of 16.3 kg, water ingestion is estimated to average 0.075 L/kg BW/d. (Note: If other body weight values are used, the water ingestion rate should be recalculated.)

Soil Ingestion

No literature data were found concerning soil ingestion by coyotes. Beyer et al. (1994) report soil consumption by red fox to be 2.8 percent of daily food consumption. Values for coyote may be comparable.

Respiration Rate

No literature data were found describing inhalation by coyote. Using Eq. 21 and assuming a body weight of 16.3 kg , the average inhalation rate is estimated to be 0.31 m^3/kg BW/d. If other body weight values are used, the inhalation rate should be recalculated.

Metabolism

Shield (1972) determined the O_2 consumption rates of several cold-acclimated Alaskan coyotes at a series of ambient temperatures; rates ranged from 7.1 mL O_2/kg/min at 20°C to 20.3 mL O_2/kg/min at -70°C. Golightly and Ohmart (1983) evaluated metabolism and body temperature of coyotes from a desert habitat in Arizona. They observed that minimum O_2 consumption occurred between 22° and 26°C and that the basal metabolic rate (BMR) within this zone was 0.0015 W/g (Golightly and Ohmart, 1983). Unlike the kit fox and other desert canids, the coyote did not exhibit any distinct daily rhythms of oxygen consumption. This may be a reflection of the coyote's irregular activity patterns (Golightly and Ohmart, 1983). Using BMR values to obtain the minimum energy intake requirements for coyotes, 129.6 J/g/d or 1296 kJ/d are required for a 10 kg coyote in thermal neutrality (Golightly and Ohmart, 1983). The minimum energy requirements for a desert coyote were calculated to be 260 J/g/d (Golightly and Ohmart, 1983).

Habitat Requirements

Coyotes are very adaptable, occupying diverse habitats ranging from forest to range to desert. Coyotes generally live in dens, built in brush-covered slopes, steep banks, rock ledges, thickets, and hollow logs. Dens of other animals, like badgers, are often used (Bekoff, 1982). Coyotes need enough food for a habitat to be suitable, but because they are opportunistic feeders they have adapted well to many diverse habitats. Coyotes in Maine prefer open habitats like bogs and frozen lakes and softwood-dominated mixed habitats to hardwood and hardwood-dominated mixed habitats (Major and Sherburne, 1987). In Michigan, coyotes prefer the mixed aspen-conifer and swamp conifer sites, as well as lowland brush habitat (Ozoga and Harger, 1966).

Home Range

The home range size of coyotes is highly variable, depending on geography and season (Bekoff, 1982). Coyotes in packs that defend ungulate carrion in the winter have compressed home ranges (1430 ha), whereas coyotes living alone or in pairs may have a home range of 3010 ha (Bekoff, 1982; Bekoff and Wells, 1980). Home range sizes have been reported as high as 6800 ha for male coyotes and as high as 3600 ha for females (Bekoff, 1982). Coyotes do not seem to exhibit territoriality unless they are in a pack (Bekoff and Wells, 1980).

Population Density

The density of coyote populations varies from year to year and by region. Fichter et al. (1955) report densities of 0.0015 individuals/ha (Fichter et al., 1955). Coyote densities in Alberta during the 1960s and 1970s varied from a low of 0.0014/ha to 0.0044/ha, depending on the abundance of their major food source, hares (Todd et al., 1981). In Michigan, densities of 0.0019/ha to 0.001/ha, have been reported (Ozoga and Harger, 1966). Other studies have found population densities of 0.001/ha to 0.023/ha (Bekoff, 1982).

Population Dynamics/Survival

The mortality rate of coyotes depends on their age and the level of control to which they are exposed. Pups and individuals less than one year of age have the highest mortality rate (67-68 percent; Bekoff, 1982). Adult mortality varies from 36-45 percent, with about 3/4 of a coyote population being between 1and 4 years of age (Bekoff, 1982). In order to maintain population stability, net survival of 33-38 percent is necessary (Knowlton, 1972; Nellis and Keith, 1976). Maximum ages of wild individuals were recorded at 13.5 years (Nellis and Keith, 1976) and 14.5 years (Knowlton, 1972).

Reproduction/Breeding

Anatomically and physiologically, coyotes are very similar to domestic dogs and can produce fertile hybrids with them, as well as with red and grey wolves and golden jackals (Bekoff, 1982). The number of females that breed in a year is dependent on food availability. Generally, 60-90 percent of adult females produce litters, along with some female yearlings (Bekoff, 1982). Knowlton (1972) estimated that approximately 87 percent of ovulated implants were represented by viable ova, with a high percentage of these developing into viable young. Gestation lasts about 63 days with an average litter size of 6 (Bekoff, 1982). Litter size can vary depending on food availability. The sex ratio in the population is about 1:1 (Bekoff, 1982). Young begin to eat solid foods at about 3 weeks of age and are usually weaned by around six weeks of age (Bekoff, 1982). During the first eight weeks of life, pup weight increases by about 0.31 kg per week, with the pups reaching adult weight at about 9 months of age (Bekoff, 1982). Emergence from the den usually coincides with pups beginning to eat solid foods.

Behavior and Social Organization

Coyotes communicate with a series of postures, gestures, tail movements, facial expressions, and vocalizations. Generally, coyotes are less social than wolves, but they will sometimes form packs. Pack formation occurs when there are large prey items to be eaten or for cooperative group defense purposes (Bekoff, 1982). Coyotes may be active at various times during the day but tend to be most active around sunrise and sunset. They also exhibit seasonal differences in activity with more time spent resting during the winter to conserve energy (Bekoff, 1982).

3.2.6 Kit Fox (*Vulpes macrotis*)[2]

Kit foxes are in the order Carnivora, family Canidae. They are closely related to the swift fox (*Vulpes velox*), with their common names having been used interchangeably in the past (Samuel and Nelson, 1982). They are carnivorous animals, and opportunistic feeders, but seem to rely mostly on rodents and lagomorphs in their diets (McGrew, 1979). While they have been exterminated from much of their historical range, populations are returning in some areas (Samuel and Nelson, 1982).

Distribution

Kit foxes are distributed throughout the desert and semiarid regions of western North America. They are historically found throughout the Sonoran, Chihuahuan, Mohave, and Painted deserts and much of the Great Basin Desert (McGrew, 1979). The similar swift fox (*Vulpes velox*) is found from New Mexico to the Dakotas (Samuel and Nelson, 1982).

Body Size and Weight

Kit foxes have a typical fox appearance, with a slim body, large ears relative to their body, and a long bushy tail (McGrew, 1979). The kit fox has a body length of about 40 cm, with the tail being 25 to 30 cm (over 40 percent of the total body length) (McGrew, 1979; Samuel and Nelson, 1982).

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[2] Text directly from Sample et al. (1997a).

Their average adult weight ranges from 1.5 to 3 kg (McGrew, 1979). Weights of kit foxes from several specific locations are listed in Table 3-14.

TABLE 3-14
Body Weights (kg) for the Kit Fox (*Vulpes macrotis)*

Location	Sex	N	Mean ± SE	Range	Reference
Utah	Male	10	2.06	1.7-2.5	Egoscue, 1962
	Female	6	1.91	1.6-2.1	
Arizona	Both: summer	11	1.77±0.06		Golightly and Ohmart, 1983
	Both: winter	9	1.87±0.06		
California	Male	21	2.4±0.01		White and Ralls, 1993
	Female	17	2.1±0.01		
Arizona	Male	4	1.82±0.06		Zoellick and Smith, 1992
	Female	3	1.67±0.04		
	Both	7	1.76±0.05		

Food Habits and Diet Composition

Kit foxes are almost exclusively carnivorous, with primary prey being small mammals and rabbits (McGrew, 1979). The endangered San Joaquin kit fox feeds almost exclusively on kangaroo rats, which are also a major food source for other subspecies of kit fox (Morrell, 1972). Egoscue (1962) found that black-tailed jackrabbits (*Lepus californicus*) made up over 94 percent of the kit foxes' diet in Utah. These differences in diet reflect the fact that kit foxes are opportunistic feeders, although not to the extent that coyotes are (McGrew, 1979). Kit foxes will supplement their diets with ground-nesting birds, reptiles, and insects but do not appear to switch to diurnal prey or move to areas of greater prey abundance when there is a decline in their primary prey species (Egoscue, 1962; Morrell, 1972; McGrew, 1979).

Food Consumption Rate

Adult kit foxes kept in captivity ate an average of 175 g fresh meat/d (Egoscue, 1962), with males consuming 108-348 g/d and females consuming 56-292 g/d. Assuming a mean body weight of 2 kg, mean food consumption equals 0.0875 g/g/d (range = 0.028-0.174 g/g/d). The total family food requirement for the first 64 days following the birth of a litter was estimated to be 44,605 g (Egoscue, 1962).

Water Consumption Rate

Kit foxes appear to obtain adequate moisture from their prey species, as they are often many kilometers away from any water source (Egoscue, 1962; Morrell, 1972). The fact that kit foxes do not utilize evaporative cooling methods for dissipating metabolic heat would support the idea that they are adapted to a low moisture, arid environment (Golightly and Ohmart, 1983).

Soil Ingestion

No literature data were found concerning soil ingestion by kit foxes. Beyer et al. (1994) report soil consumption by red foxes to be 2.8 percent of daily food consumption. Values for kit foxes may be comparable.

Respiration Rate

No literature data were found describing inhalation by kit foxes. Using Eq. 21 and assuming a body weight of 1.5 to 3 kg, the average inhalation rate is estimated to range from 0.44 m^3/kg BW/d to 0.5 m^3/kg BW/d. If other body weight values are used, the inhalation rate should be recalculated.

Metabolism

Golightly and Ohmart (1983) studied metabolism and body temperatures of kit foxes and other desert canids from Arizona. The minimum summer oxygen consumption rate was observed between 19° and 31°C; minimum O_2 consumption in winter occurred between 23° and 33°C (Golightly and Ohmart, 1983). BMR was 0.0034 W/g in summer and 0.0028 W/g in winter. Kit fox metabolic rates are not consistent with those of other desert-adapted species. Instead, kit foxes exhibit high thermal conductance, which may be an adaptation for dissipating heat loads by nonevaporative means. Foxes may use dens during the day and limit their activities to the night to avoid excessive heat and water loss (Golightly and Ohmart, 1983). The kit fox cannot tolerate high ambient temperatures, and the den provides safety and a predictable shelter with a moderated microclimate. Kit foxes also exhibited distinct circadian rhythms in oxygen consumption and body temperature, with peak levels corresponding to early evening and early morning activity periods (Golightly and Ohmart, 1983). This is unlike the coyote and allows metabolic rate and water loss to be minimized in the kit fox.

Habitat Requirements

Kit foxes prefer semiarid habitats with less than 20 percent ground cover, light colored loamy desert soil, and elevations lower than 1675 ft (McGrew, 1979). The vegetation of these areas is a shrubby or shrub-grass combination that varies depending on the actual location.

Home Range

Home ranges of kit foxes overlap broadly with different family hunting groups hunting in the same areas but not at the same time. This suggests that no specific hunting territory is maintained or defended (Morrell, 1972). Morrell (1972) estimated the home range of kit foxes in the San Joaquin Valley of California to be 260 to 520 ha. Zoellick and Smith (1992) calculated the overall average home range size to be 1120 ± 94 ha for foxes in western Arizona. The male home range averaged 1230 ± 100 ha, and the female home range averaged 980 ± 140 ha. White and Ralls (1993) calculated the home range of kit foxes in California to average 1160 ± 90 ha. White and Ralls (1993) also calculated a mean social group home range of 1370 ± 110 ha.

Population Density

In Utah, Egoscue (1956) estimated the population density of the kit fox to be 0.001 pairs/ha, or at an optimum, 0.008 individuals/ha. Zoellick and Smith (1992) found population densities of 0.0022-0.0028 individuals/ha in western Arizona. White and Ralls (1993) estimated minimum population densities of 0.0015-0.0024 individuals/ha in California. In 1959, the population of the

San Joaquin kit fox was estimated to be between 1000 and 3000 total, or about 0.004 individuals/ha (Samuel and Nelson, 1982).

Population Dynamics/Survival

The mortality rates of kit foxes are unknown, but their overall abundance has declined dramatically as a result of poisoning and trapping; habitat loss has contributed to the decline (Zoellick et al., 1989). Some fox mortality is the result of being hit by cars and by predation by coyotes and hawks (Egoscue, 1962). Most of the kit fox populations that have been studied remain at a relatively stable size, presumably at a level that can be supported by the environment. Egoscue (1956, 1962) and others have often seen a slight bias toward the number of males in the adult kit fox population. Population numbers have been observed to rise or fall depending on the population of their major food source (Egoscue, 1962; Morrell, 1972). During a period of low food supply, Egoscue noted that average adult age was only 1.96 years.

Reproduction/Breeding

Males will generally join females at natal dens in October or November, with breeding occurring between December and February (McGrew, 1979). Initial observations suggested kit foxes to be monogamous (Egoscue, 1962); however, recent research indicates multiple females sharing a den with one male (Morrell, 1972). Little is known about courtship behavior, but copulation appears to be similar to other canids. The gestation period in kit foxes in unknown but is assumed to be about the same as the red fox, 49-55 days (Egoscue, 1962). Litters are usually born in February or March, with a litter size of 4-5 and a nearly even sex ratio (Egoscue, 1962; Morrell, 1972; Samuel and Nelson, 1982). The male fox stays with the family and hunts for food while the female suckles the pups and rarely leaves the den (McGrew, 1979). Pups emerge from the den in about a month and reach adult weight by about five months of age. The family group will split up in October, with the pups usually dispersing beyond their parents home range (Morrell, 1972).

Behavior and Social Organization

Few detailed accounts exist of kit fox behavior, although there is some information on reproduction, hunting, and denning (McGrew, 1979). Foxes appear to use olfactory clues, similar to other canids, and Egoscue (1962) has described several kit fox vocalizations. Morrell (1972) also described some of these vocalizations. Some of the lack of information on behaviors is because of the nocturnal habits of the kit fox. Dens are a very important part of the kit fox's life, with most having multiple entrances, anywhere from 2 to 24 (Egoscue, 1962). A suitable den is a critical habitat component for the kit fox, as dens are used throughout the year (Samuel and Nelson, 1982). Family groups tend to have a whole group of dens that they use almost exclusively, but this may change from year to year (Egoscue, 1956, 1962). Smaller dens are used during the breeding season and larger dens are used during the winter (Samuel and Nelson, 1982). Several researchers have also recently investigated the spacing patterns of kit foxes and their nightly movements (White and Ralls, 1993; Zoellick et al., 1989; Zoellick and Smith, 1992).

3.2.7 Mink (*Mustela vison*)[1]

Mink are in the order Carnivora, family Mustelidae. Although varied in size, most members of this family have long, slender bodies and short legs. Throughout the family, the male is usually larger than the female. The more terrestrial species feed primarily on small mammals and birds. Mustelids that live around lakes and streams feed on aquatic prey such as fish, frogs, and invertebrates (Burt and Grossenheider, 1980). The mink is the most abundant and widespread carnivorous mammal in North America.

Distribution

Mink are distributed throughout North America, except in the extreme north of Canada, Mexico, and arid areas of the southwestern United States. It is common throughout its range but often overlooked because of its solitary nature and nocturnal activity.

Body Size and Weight

Body size varies greatly throughout the species' range, with males weighing markedly more than females (in some populations, almost twice as much, see Table 3-15). Males measure from 33 to 43 cm with a 18 to 23 cm tail. Females measure from 30 to 36 cm with a 13 to 20 cm tail (Burt and Grossenheider, 1980). Farm-raised mink tend to be larger than wild mink (letter from R. J. Aulerich, Department of Animal Science, Michigan State University, East Lansing, MI, to Susan Norton, January 7, 1992).

TABLE 3-15
Body Weight (g) Mink, *Mustela vison*

Location	Sex	N	Mean	Range	Reference
Western Races	Male			< 2,300	Harding, 1934
Eastern races	Male			< 1,400	Harding, 1935
Michigan (farm raised)	Male (spring)		1,734 ± 350		Hornshaw et al., 1983
	Female (spring)		974 ± 202		
Montana	Adult Male (summer)		1,040		Mitchell, 1961
	Juvenile Male (summer)		777		
	Adult Male (Fall)		1,233		
	Juvenile Male (Fall)		952		
	Adult Female (summer)		550		
	Juvenile Female (summer)		533		
	Adult Female (Fall)		586		
	Juvenile Female (Fall)		582		
NS	neonate			6 - 10	Eagle and Whitman, 1987
Michigan (farm raised)	neonate		8.3 ± 1.54		Hornshaw et al., 1983

[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

Food Habits and Diet Composition

Mink are predominantly nocturnal hunters, although they are sometimes active during the day. Shorelines and emergent vegetation are the mink's principal hunting areas (Arnold, 1986, cited in Eagle and Whitman, 1987). Mink are opportunistic feeders, taking whatever prey is abundant (Hamilton, 1936a, 1940; Errington, 1954; Sargeant et al., 1973). Mammals are the mink's most important prey year-round in many parts of their range (Eagle and Whitman, 1987), but mink also hunt aquatic prey such as fish, amphibians, and crustaceans and other terrestrial prey such as bird, reptiles, and insects, depending on the season (Linscombe et al., 1982). In marsh habitats in summer, muskrats can be an important food source depending on their population density and vulnerability (e. g., health) (Hamilton, 1940a; Sealander, 1943; Errington, 1954). Mink diet also can depend on marsh water level; Proulx et al. (1987) found that with high water levels, mink captured predominantly crayfish and meadow voles, but during periods of low water, the mink preyed on aquatic birds and muskrats deeper in the marsh. Similarly, Errington (1939) found that mink predation on muskrats in the prairie pothole region can increase dramatically in times of drought as the muskrat burrows become more exposed. Also in this region, ducklings and molting adult ducks that frequent shorelines are particularly vulnerable to mink predation (Arnold and Fritzell, 1987; Sargeant et al., 1973). In winter, mink often supplement their diet with fish (Eagle and Whitman, 1987). Females tend to be limited to smaller prey than males, who are able to hunt larger prey such as rabbits and muskrats more successfully (Birks and Dunstone, 1985; Sealander, 1943).

Mink are particularly sensitive to PCBs and similar chemicals, and have been found to accumulate PCBs in subcutaneous fat to 38 to 200 times dietary concentrations, depending on the PCB congener (Hornshaw et al., 1983).

TABLE 3-16
Diet Consumption of Mink, *Mustela vison*

Location	Prey Taxon	Spring	Summer	Fall	Winter	Reference
Manitoba, Canada	ducks	5.2	32.5			Arnold and Fritzell, 1987
Aspen parklands	other birds	18.8	21.6			
of prairie potholes	eggs	3.3	14.5			(% dry weight in scats, male mink only)
	muskrats	42.0	2.1			
	ground squirrels	14.2	0.5			
	other mammals	15.5	25.3			
	insects	1.0	3.5			
Michigan, stream	Habitat (season)	Stream (year-round)		River (year-round)		Alexander, 1977
River	trout	52		56		
	non-trout fish	6		26		(% wet weight, stomach contents)
	unidentified fish	3		3		
	crustaceans	11		4		
	amphibians	2		3		

TABLE 3-16
Diet Consumption of Mink, *Mustela vison*

Location	Prey Taxon	Spring	Summer	Fall	Winter	Reference
	birds/mammals	5		6		
	vegetation	17		1		
	unidentified	4		1		
Michigan	(sex of mink)				(M) (F)	Sealander, 1943
	muskrat				43 14	
	cottontail				16 12	(% wet weight, stomach contents)
	small mammals				5 17	
	large birds				18 11	
	small birds				trace	
	snakes				2 2	
	frogs				10 37	
	fish				5 4	
	crayfish				1 3	
Missouri	frogs				24.9	Korschgen, 1958
	mice and rats				23.9	
	fish				19.9	(% dry volume; stomach contents)
	rabbits				10.2	
	crayfish				9.3	
	birds				5.6	
	fox squirrels				2.2	
	muskrats				1.3	
	other				2.7	

Food Consumption Rate

Measurements on food consumption rates have been obtained primarily form captive and farm raised animals. Arnold and Fritzell (1987) found the average summer food ingestion rate for a captive males was 0.13 g/g-day. Farm raised mink in Michigan were found to have an average winter food ingestion rate of 0.12 and 0.16 g/g-day for males and females, respectively (Bleavins and Aulerich, 1981). The year round food consumption for an average male is estimated at 0.22 g/g-day using Eq. 5 and summer body weights from Mitchell (1961), and dietary composition of Alexander (1977). (Note: If using different body weights, then the rate should be recalculated.)

Water Consumption Rate

Water ingestion rates for the average adult female mink is 0.11 and 0.099 L/kg BW/day for the average adult male, based on Eq. 19 and body weights from Mitchell (1961). Farrell and Wood (1968c) found that the average water ingestion rate of a farm raised adult female, fed a diet containing 69 percent water, was 0.028 L/kg BW/day. (Note: If using different body weights, then the rate should be recalculated).

Soil Ingestion

No soil ingestion data was available in the literature; however, Hamilton (1940a) noted sand in 1.3 percent of mink scat collected. Additionally, a soil ingestion rate of 2 percent is the minimum reported for 15 mammals in Beyer et al. (1994). Therefore, it is recommended that 2 percent be used for mink.

Respiration Rate

Inhalation rates were not available in the literature. Inhalation rates of 0.61 m^3/kg BW/day for females and 0.53 m^3/kg BW/day for males were estimated using Eq. 21 and mean adult body weights from Mitchell (1961). (Note: If using different body weights, then the rate should be recalculated).

Metabolism

Harper et al. (1978) evaluated the energy requirements of growing farm-raised male mink during a 21-day period when about 20 percent of their total growth would occur. They expressed food intake on the basis of metabolic body size (MBS) instead of body weight (BW) where MBS = BW(kg) . Metabolizable energy (ME) requirements were 147.8 ± 6.06 (kcal/kg - day). Accounting for assimilation efficiency, this corresponded to a gross energy (GE) intake of approximately 203 (kcal/kg $_{MBS}$ -day).

Iversen (1972) found that basal metabolic rate for mink and other mustelids weighing 1 kg or more could be expressed by the equation:

$$BMR = 84.6Wt\ (\pm 0.15),\ 0.78$$

where, BMR = basal metabolic rate in kcal/day and Wt = body weight in kilograms.

This model reflects the finding that the larger mustelids have a slightly (10 to 15 percent) higher basal metabolic rate than expected for mammals in general. Mustelid species much smaller than 1 kg (i. e., the stoat and weasel) have much higher basal f metabolic rates than predicted for mammals in general. Free-living metabolic rates would be expected to be three to five times higher, estimated at 258 and 236 kcal/kg BW/day for average adult females and males respectively, based on the equation in Nagy (1987) and body weights form Mitchell (1961). Farm raised female mink had metabolic rates of 258 kcal/kg BW/day (Farrell and Woods, 1968b). (Note: if using different body weights, then the rates should be recalculated)

Habitat Requirements

Mink are found associated with aquatic habitats of all kinds, including waterways such as rivers, streams, lakes, and ditches, as well as swamps, marshes, and backwater areas (Linscombe et al., 1982). Mink prefer irregular shorelines to more open, exposed banks

(Allen, 1986a). They also tend to use brushy or wooded cover adjacent to the water, where cover for prey is abundant and where downfall and debris provide den sites (Allen, 1986a).

Home Range

The home range of mink encompasses both their foraging areas around waterways and their dens. When denning, mink use bank burrows of other animals, particularly muskrats, as well as cavities in tree roots, rock or brush piles, logjams, and beaver lodges (Melquist et al., 1981; Birks and Linn, 1982; Eagle and Whitman, 1987). Individual mink may use several different dens within their home range, males more so than females (Birks and Linn, 1982). Melquist et al. (1981) found that den sites in Idaho were 5 to 100 m from the water, and they never observed mink more than 200 m from water. The shape of mink home ranges depends on habitat type; riverine home ranges are basically linear, whereas those in marsh habitats tend to be more circular (Birks and Linn, 1982; Eagle and Whitman, 1987). Home range size depends mostly on food abundance, but also on the age and sex of the mink, season, and social stability (Arnold, 1986; Birks and Linn, 1982; Eagle and Whitman, 1987; Linn and Birks, 1981; Mitchell, 1961).

In winter, mink spend more time near dens and use a smaller portion of their home range than in summer (Gerell, 1970, cited in Linscombe et al., 1982). Adult male home ranges are generally larger than adult female home ranges (Eagle and Whitman, 1987), particularly during the mating season when males may range over 1,000 ha (Arnold, 1986). In the prairies of North Dakota the mink's home range was between 259 and 380 ha. (Eagle unpublished. Cited in Allen 1986a). In the prairie pothole regions of Manitoba adult males ranged over 770 ha (Arnold and Fritzell, 1987). Mitchell (1961) found a difference in the home range size of adult female minks in riverine habitats of Montana depending on whether the vegetation was heavy or sparse. Sparse vegetation resulted in a much larger home range of 20.4 ha, while heavily vegetated areas resulted in a home range of only 7.8 ha. In streams in Sweden adult males had ranges of 2.63 km (1.80 to 5.0 km) while females had smaller ranges of 1.85 km (1.0 to 2.8 km) (Gerrell, 1970). Juvenile males had even smaller home ranges of 1.23 km (1.1 to 1.4 km).

Population Density

Population density depends on available cover and prey. Population densities typically range from 0.01 to 0.10 mink/ha. In Montana, the mink densities were between 0.03 and 0.085 mink/ha. (Mitchell, 1961). In Michigan during the winter months, female mink were less dense at 0.006 mink/ha. (Marshall, 1936). In riverine environments, it can be more meaningful to measure densities in terms of number of mink per unit length of shoreline covered rather than in terms of number per hectare. Marshall (1936) found female mink density to be 0.6 mink/km of river.

Population Dynamics/Survival

Mink reach sexual maturity at 10 months to a year and may reproduce for 7 years, possibly more (Enders, 1952; Ewer, 1973). Female mink can reproduce once per year and usually give birth to their first litters at the age of 1 year (Hall and Kelson, 1959; Eagle and Whitman, 1987). Females often live to the age of 7 years in captivity (Enders, 1952), but have lived up to 10 years in a zoo environment (Eisenberg, 1981) and up to 11 years at a mink farm (Enders, 1952).

Reproduction/Breeding

Mating occurs in late winter to early spring (Eagle and Whitman, 1987) with peak mating in April, March and fall in Alaska, Montana, and Floriday cypress swamps, respectively (Burns, 1964; Mitchell, 1961; Humphrey and Zinn, 1982). Variation in the length of mating season with different subspecies reflects adaptations to different climates (Linscombe et al., 1982). Ovulation is induced by mating and implantation is delayed (Eagle and Whitman, 1987). Gestation is 51 days (40- 75) in captivity (Enders, 1952) and between 39 to 76 days over North America (Hall and Kelson, 1959). Parturition generally occurs in the late spring, and the mink kits are altricial (helpless) at birth (Linscombe et al., 1982). Mean litter sizes are 4.2 for farm-raised mink (Hornshaw et al., 1983) and 4 (range of 2-8) for mink inhabiting riverine areas of Montana (Mitchell, 1961). Hall and Kelson (1959) reported a litter size range of 4-10 kits in North American mink. Mink can eat meat at an age of 37 days (Svihla, 1931) and are fully homeothermic at 7 weeks (Kostron and Kukla, 1970).

Behavior and Social Organization

Mink are generally solitary, with females only associating with their young of the year. Female home ranges generally do not overlap with the home ranges of other females, nor do the home ranges of males overlap with each other (Eagle and Whitman, 1987). The home range of a male may overlap the home range of several females, however, particularly during the breeding season (Eagle and Whitman, 1987).

In winter, mink do not undergo hibernation or torpor; instead, they are active year-round. Mink replace their summer coat in mid to late fall with a darker more dense coat and molt again in the spring (Eagle and Whitman, 1987; Linscombe et al., 1982).

3.2.8 Red Fox (*Vulpes vulpes*)[1]

Red foxes are in the order Carnivora, family Canidae. Unlike the more social wolves, foxes tend to hunt alone. Foxes are most active at night, and are primarily carnivorous, preying predominantly on small mammals, but they also eat insects, fruits, berries, seeds, and nuts. Foxes are found throughout most of the United States and Canada, including the arctic.

Distribution

Red foxes are present throughout the United States and Canada except in the southeast, extreme southwest, and parts of the central states. Twelve subspecies are recognized in North America (Ables, 1974).

Body Size and Weight

The dog-sized red fox has a body about 56 to 63 cm in length, with a 35 to 41 cm tail (Burt and Grossenheider, 1980). They weigh from 3 to 7 kg, with the males usually outweighing the females by about 1 kg (Voigt, 1987).

[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

TABLE 3-17
Body Weights (Kg) for the Red Fox, *Vulpes vulpes*

Location	Sex	N	Mean	Reference
Illinois	Male (spring)	NS[a]	5.25$\pm$0.18[b]	Storm et al., 1976
	Female (spring)	NS	4.13$\pm$0.11[b]	
Iowa	Male (fall)	NS	4.82$\pm$0.08[b]	Storm et al., 1976
	Female (fall)	NS	3.94$\pm$0.08[b]	
Wisconsin	Neonate at	NS	0.102$\pm$0.12[b]	Storm and Ables, 1966
North Dakota	Weaning	NS	0.70	Sargeant, 1978

[a] Not stated
[b] mean $\pm$ standard deviation of means for n samples

Food Habits and Diet Composition

Red fox prey extensively on mice and voles but also feed on other small mammals, insects, hares, game birds, poultry, and occasionally seeds, berries, and fruits (Palmer and Fowler, 1975; Korschgen, 1959; Samuel and Nelson, 1982). Meadow voles are a major food in most areas of North America; other common prey include mice and rabbits (Korschgen, 1959; Voigt, 1987). Game birds (e. g., ring-necked pheasant and ruffed grouse) and waterfowl are seasonally important prey in some areas (Pils and Martin, 1978; Sargeant, 1972; Voigt and Broadfoot, 1983). Plant material is most common in red fox diets in summer and fall when fruits, berries, and nuts become available (Johnson, 1970; Major and Sherburne, 1987). Red foxes often cache food in a hole for future use (Samuel and Nelson, 1982). They also are noted scavengers on carcasses or other refuse (Voigt, 1987). Most activity is nocturnal and at twilight (Nowak and Paradiso, 1983). The diet composition of red foxes is detailed in Table 3-16.

Food Consumption Rate

Sargeant (1978) reports on food ingestion rates for red fox juveniles and adults in laboratory and captive populations in North Dakota. Ingestion rates were highest in young juveniles between 5 and 8 weeks with an average rate of 0.16 g/g-day. Juveniles between 9 and 12 weeks averaged 0.12 g/g-day and those between 13 and 24 weeks were at 0.11 g/g-day. Food consumption for an adult pair 11 days prior to whelping (i.e. parturition) and of the adult female for the first four weeks after whelping were 0.075 and 0.14 g/g-day respectively. The average consumption rate for a non-breeding adult was 0.069 g/g-day.

Using Eq. 5 and assuming a mean body weight of 0.0045 kg (as calculated from the above table using adults) a food ingestion rate of 0.180 kg/kgBW/d was estimated. A fresh weight of 0.015 kg/kgBW/day was calculated using Eq. 18 and assuming a diet of 81.4 percent mammals, 4.8 percent birds, 2.8 percent insects, and 7 percent plants (Hockman and Chapman, 1983) with respective water contents of 68, 68, 61, and 85 percent as presented in Table 3-4.

Water Consumption Rate

The water ingestion of an average adult male red fox is 0.084 g/g-day and 0.086 for an average adult female, based on Eq. 19 and body weights from Storm et al. (1976). (Note: If using different body weights, then the rate should be recalculated.)

TABLE 3-18
Diet Consumption of Red Fox (*Vulpes vulpes*), % Wet Volume; Stomach Contents, *Vulpes vulpes*

Location	Prey Taxon	Spring	Summer	Fall	Winter	Reference
Nebraska	Rabbits				44.4	Powell and Case, 1982
	Small Mammals				33.0	
	Pheasant				8.4	
	Other Birds				11.2	
	Misc.				2.0	
	Not Accounted For				1.0	
Illinois	Mammals	92.2	37.1	61.7	65.0	Knable, 1974
	Birds	2.4	43.2	0.2	8.6	
	Arthropods	0.2	11.6	4.2	<0.1	
	Plants	4.6	6.3	31.1	26.1	
	Unspecified/Other	0.6	1.8	2.8	0.3	
Missouri	Rabbits	24.8	10.7	36.5	38.7	Korschgen, 1959
	Mice/Rats	24.2	6.2	21.3	22.5	
	Other Mammals	4.0	1.4	8.1	8.2	
	Poultry	21.0	45.0	16.3	11.6	
	Carrion	12.9	13.0	6.5	7.4	
	Livestock	9.8	0.3	2.0	5.4	
	Birds	0.6	1.2	1.1	3.8	
	Invertebrates	trace	15.3	1.6	trace	
	Plant Foods	2.7	6.9	6.6	2.1	
Maryland/ Appalachian Province	Mammals				81.4	Hockman and Chapman, 1983
	Birds				4.8	
	Arthropods				2.8	
	Plants				7.0	
	Unspecified/Other				4.0	

Soil Ingestion

A soil ingestion rate of 2.8 percent of the diet was estimated for the red fox by Beyer et al. (1994).

Respiration Rate

Respiration rates can be calculated using Eq. 21 and body weights from Storm et al. (1976). The estimated rate for males was 0.39 m^3/kgBW/day while females had a rate of 0.41m^3/kgBW/day.(Note: If using different body weights then the rate should be recalculated).

Metabolism

Laboratory studies with juveniles found an average summer metabolism rate of 193 $\pm$ 56 kcal/kg-day (Vogtsberger and Barrett, 1973). The estimated average basal metabolism for an adult male is 47.9 kcal/kg-day, and 51.1 kcal/kg-day for an adult female. These estimations are based on the equation in Boddington (1978) and body weights from Storm et al. (1976). The average metabolic rates for free living adult males and females are 161 and 168 kcal/kg-day respectively, based on the equation in Nagy (1987) and body weights from Storm et al. (1976). (Note: if using different body weights rates should be recalculated.)

Habitat Requirements

As the most widely distributed carnivore in the world, the red fox can live in habitats ranging from arctic areas to temperate deserts (Voigt, 1987). Red foxes utilize many types of habitats, including cropland, rolling farmland, brush, pastures, hardwood stands, and coniferous forests (MacGregor, 1942; Eadie, 1943; Cook and Hamilton, 1944; Ables, 1974). They prefer areas with broken and diverse upland habitats such as occur in most agricultural areas (Ables, 1974; Samuel and Nelson, 1982; Voigt, 1987). They are rare or absent from continuous stands of pine forests in the southeast, moist conifer forests along the Pacific coast, and semiarid grasslands and deserts (Ables, 1974).

Home Range

The home ranges of individuals from the same family overlap considerably, constituting a family territory (Sargeant, 1972; Voigt and MacDonald, 1984). Territories of neighboring red fox families are largely nonoverlapping and contiguous, usually resulting in all parts of a landscape being occupied by foxes. Territory sizes range from less than 50 to over 3000 ha. Red foxes in alpine territories of British Columbia tend to have large home ranges during summer, averaging 1611 ha (Jones and Theberge, 1982). The adult female's range was smaller than the male's averaging 1137 ha compared to 1967 ha for males (Jones and Theberge, 1982). Adult females ranged only 699 ha during spring in Minnesota fields and swamps (Sargeant, 1972). In Wisconsin, female red foxes ranged over 96 ha while males ranged over 717 ha (Ables, 1969). Territories in urban areas tend to be smaller than those in rural areas (Ables, 1969).

Adults visit most parts of their territory on a regular basis; however, they tend to concentrate their activities near to their dens, preferred hunting areas, abundant food supplies, and resting areas (Ables, 1974; Keenan, 1981). Territory boundaries often conform to physical landscape features such as well-traveled roads and streams (Ables, 1974). Territory defense is primarily by nonaggressive mechanisms involving urine scent-marking and avoidance behaviors. Scent marking occurs throughout the territory; there is little patrolling of territory boundaries. Each fox or family usually has a main underground den and one or more other burrows within the home range (Nowak and Paradiso, 1983). Most dens are abandoned burrows of other species (e.g., woodchucks, badgers)(Samuel and Nelson, 1982). Tunnels are up to 10 m in length and lead to a chamber 1 to 3 m below the surface (Nowak and Paradiso, 1983). Pup-rearing dens are the focal point of fox activity during spring and early summer. Foxes have some rest sites and usually forage away from the den (Voigt, 1987).

Population Density

One red fox family per 100 to 1000 ha is typical in Canada, with the highest densities found in southern habitats of Ontario and the lowest densities found in the northern boreal forests and arctic tundra (Voigt, 1987). Red foxes have larger home ranges where population densities are low and in poorer habitats (Voigt, 1987). Ables (1974) observed 0.046-0.077 red fox per ha in areas of North American considered "good fox range." Most young foxes, especially males, disperse before the age of 1 (Voigt, 1987), usually during September to March, with peaks in dispersal in October and November (Phillips et al., 1972; Storm et al., 1976).

Population Dynamics/Survival

Foxes usually produce pups their first year, except in extremely high density areas and in some years in northern portions of their range where they may delay breeding until the next season (Allen, 1984; Harris, 1979; Storm et al., 1976; Voigt and MacDonald, 1984). Red foxes produce 1 litter per year (Samuel and Nelson, 1982). Litter size generally averages four to six pups. In upper Michigan and the prairie potholes of North Dakota, litter sizes averaged 4.2 and 4.1, respectively (Switzenberg, 1950 and Allen, 1984). In contrast, litter size in red foxes breeding in the farms and woods of Iowa and Illinois were 6.7 and 6.8, respectively (Storm et al., 1976). Litter size was intermediate at 5.5 pups in the farms, marshes, and pastures of Wisconsin (Pils and Martin, 1976).

The pups leave the den about 1 month after birth, and they are weaned by about 8 to 10 weeks of age (Ables, 1974). Red foxes incur high mortality rates as a result of shooting, trapping, disease, and accidents (e. g., roadkills) (Storm et al., 1976). Mortality rates in Wisconsin are 79.4 percent (Pils and Martin, 1978). Juveniles have an even higher rate of mortality with males at 83 percent and females at 81 percent (Storm et al., 1976). Adult females have the lowest mortality rate at 74 percent (Storm et al., 1976). Two factors that tend to limit red fox abundance are competition with other canids, especially coyotes, and seasonal limits on food availability (Voigt, 1987). Fecundity is higher in areas of high mortality and low population densities (Voigt, 1987).

Reproduction/Breeding

Breeding occurs earlier in the south, usually beginning in early or late December, and is delayed until late January or February in the more northern ranges (Samuel and Nelson, 1982; Voig, 1987; Storm et al., 1976; Layne & McKeon, 1956). Females reach sexual maturity at 10 months (Storm et al., 1976). A mated pair maintains a territory throughout the year, with the male contributing more to its defense than the female (Preston, 1975). Gestation is between 51 and 54 days (Sheldon, 1949). Pups are born and reared in an underground den, and the male assists the female in rearing young and provides food for the pups (Samuel and Nelson, 1982). Pups first emerge from the den when 4 to 5 weeks old (Samuel and Nelson, 1982), gaining 15.9 grams per day from birth to weaning (Sargeant, 1976).

Behavior and Social Organization

Once considered solitary, red foxes now are reported to exhibit more complex social habits (MacDonald and Voigt, 1985). A fox family, the basic social unit, generally consists of a mated pair or one male and several related females (MacDonald, 1980; Voigt, 1987). The additional females are usually nonbreeders that often help the breeding female (Voigt, 1987).

3.2.9 Northern River Otter (*Lutra canadensis*)[1]

River otters are in the order Carnivora, family Mustelidae. Mustelids have long, slender bodies, short legs, and anal scent glands. Throughout the family, the male is usually larger than the female. The more terrestrial species of this family occupy various habitats and feed primarily on small mammals and birds. Mustelids that live around lakes and streams feed primarily on

[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

aquatic species such as fish, frogs, and invertebrates (Palmer and Fowler, 1975; Burt and Grossenheider, 1980).

Distribution

The northern river otter historically lived throughout much of the North American continent (Hall, 1981). Currently, many populations along the coastal United States and Canada are stable or increasing, but this species is rare or extirpated throughout much of the midwestern United States (Toweill and Tabor, 1982).

Body Size and Weight

River otters measure 66 to 76 cm with a 30 to 43 cm tail. Sexual dimorphism in size is seen among all subspecies (Harris, 1968; van Zyll de Jong, 1972, cited in Toweill and Tabor, 1982), and adult males (5 to 10 kg) outweigh females (4 to 7 kg) by approximately 17 percent (Melquist and Hornocker, 1983; see Table). Full adult weight generally is not attained until sexual maturity after 2 years of age (Melquist and Hornocker, 1983). Along the Pacific Coast, there is some evidence that size decreases from north to south (Toweill and Tabor, 1982).

TABLE 3-19
Body Weights (kg) of River Ottter, *Lutra canadensis*

Location	Sex	N	Mean	Range	Reference
Throughout Range	Both			5.0-15	Melquist and Dronkert, 1987
Alabama, Georgia	Adult Male		8.13 ± 1.15	5.84 - 10.4	Lauhachinda, 1978
	Adult Female		6.73 ± 1.00	4.74 - 8.72	
	Young Male		6.36 ± 0.98	4.41 - 8.31	
	Young Female		5.83 ± 1.82	3.75 - 7.01	
wc Idaho	Adult Male		9.20 ± 0.6		Melquist and Hornocker, 1983
	Adult Female		7.90 ± 0.2		
	Young Male		7.0 ± 0.4		
	Young Female		7.20 ± 0.1		
New York	neonate		0.132		Hamilton and Eadie, 1964
Alabama, Georgia	neonate		0.140 to 0.145		Hill and Lauhachinda, 1981

Food Habits and Diet Composition

Otters usually are active in the evening and from dawn to midmorning, although they can be active any time of day (Melquist and Hornocker, 1983). The bulk of the river otter's diet is fish; however, otters are opportunistic and will feed on a variety of prey depending on availability and ease of capture. River otters take different fish species according to their availability and how well the fish can escape capture (Loranger, 1981).

Depending on availability, otters also may consume crustaceans (especially crayfish), aquatic insects (e. g., stonefly nymphs, aquatic beetles), amphibians, terrestrial insects, birds (e. g., ducks), mammals (e. g., young beavers), and turtles (Burt and Grossenheider, 1980; Lagler and Ostenson, 1942; Liers, 1951b; Melquist and Hornocker, 1983; Palmer and Fowler, 1975; Toweill and Tabor, 1982). Gilbert and Nancekivell (1982) observed that otters consume more waterfowl in the northerly latitudes than in the south, probably because of the ease of capturing the waterfowl during their molt in the north. Otters probe the bottoms of ponds or streams for invertebrates and may ingest mud or other debris in the process (Liers, 1951b). Because of its piscivorous diet and high trophic level, the river otter is a noteworthy indicator of bioaccumulative pollution in aquatic ecosystems (Melquist and Dronkert, 1987).

TABLE 3-20
Diet Consumption of River Otter, *Lutra canadensis*

Location/Habitat	Prey Taxon	Spring	Summer	Fall	Winter	Reference
wc Idaho/mountain streams and lakes	fish	100	93	97	99	Melquist and Hornocker, 1983
	(sucker)	(52)	(47)	(17)	(30)	
	(sculpins)	(40)	(31)	(38)	(42)	(percent frequency of occurrence in scats)
	(squawfish)	(5)	(4)	(1)	(6)	
	(perch)	(22)	(3)	(7)	(9)	
	(whitefish)	(21)	(10)	(24)	(66)	
	invertebrates	2	7	10	12	
	birds	<1	12	1	<1	
	mammals	1	4	3	1	
	reptiles	0	1	0	0	
nw Montana/lakes and streams	invertebrates	41.6	44.2	33.3	26.3	Greer, 1955
	(aquatic insects)	19.6	19.2	10.7	4.0	
	(fr water shrimp)	14.3	8.9	10.7	4.0	(percent frequency of occurrence in scats)
	fish	91.4	92.9	100	100	
	(trout)	23.7	9.8	33.3	29.3	
	(sculpin)	20.5	20.9	21.3	25.3	
	(sunfish)	47.1	72.8	60.0	33.3	
	frog	19.6	19.2	10.7	9.1	
	salamander	0.3	0.7	1.3	--	
	snake	0.2	0.7	--	--	
	birds	6.7	4.1	1.3	1	
	mammals	8.1	5.3	2.7	4.0	
nw Illinois/Mississippi River	fish	97	69	98	99	Anderson and Woolf, 1987b
	(sunfish)	(31)	(31)	(80)	(52)	
	(minnow/carp)	(52)	(0)	(17)	(44)	(percent frequency of occurrence in scats)
	(herring)	(49)	(38)	(10)	(40)	
	(bass)	(26)	(0)	(5)	(14)	
	frog	3	6	11	16	
	crayfish	12	50	8	7	
	dragonfly nymphys	2	0	6	2	
	birds	4	13	3	1	
Michigan/NS	game and pan fish	32				Lagler and Ostenson, 1942
	forage fish	17.6				
	fish remains	3.0				% volume; stomach contents
	amphibians	16.1				
	other invertebrates	25.8				

Food Consumption Rate

Otters in captivity required 700-900 g of food daily (Harris, 1968, cited in Toweill and Tabor, 1982). Using Eq. 5 and assuming a mean body weight of 0.008 Kg (calculated using the above table and adults) a food consumption rate of 0.16 kg/kg BW/day was estimated. To determine a fresh weight food ingestion rate (0.64 kg/kgBW/day), a diet of predominantly fish (Anderson and Woolf, 1987b) was assumed with a water content of 75 percent (Table 3-4). (Note: If using different body weights, the rate should be recalculated).

Water Consumption Rate

Water consumption rate for the average adult male is 0.080 L/kg BW/day and for an average adult female 0.082 L/kg BW/day, based on Eq. 19 using body weights from Lauhachinda (1978). (Note: If using different body weights, then the rate should be recalculated).

Soil Ingestion

No data was available on soil ingestion in the literature. Because river otters are primarily piscivorous (Loranger, 1981), soil ingestion is likely to be negligible.

Respiration Rate

No literature data were available for inhalation rates in river otters. The estimated respiration rate for the average adult male is 0.36 m^3/kg BW/day and for an average adult female is 0.37 m^3/kg BW/day, based on Eq. 21 using body weights from Lauhachinda (1978). (Note: If using different body weights then rate should be recalculated.)

Metabolism

Iversen (1972) found that basal metabolic rate of otters and other mustelids weighing 1 kg or more could be expressed by the equation:

$$BMR = 84.6(BW^{0.78}) (\pm 0.15)$$

where, BMR = basal metabolic rate in kcal/day and BW = body weight in kilograms.

Free-living metabolic rates would be expected to be three to five times higher, 183 and 178 kcal/kg BW/day for adult females and males, respectively, based on the equation in Nagy (1987) and using body weights from Lauhachinda (1978). Estimated basal metabolic rates of adult males are 42.6kcal/kg BW/day and females are 44.8 kcal/kg BW/day using the equation in Boddington (1978) and body weights from Lauhachinda (1978).

Habitat Requirements

Almost exclusively aquatic, the river otter is found in freshwater, estuarine, and some marine environments all the way from coastal areas to mountain lakes (Toweill and Tabor, 1982). They are found primarily in food-rich coastal areas, such as the lower portions of streams and rivers, estuaries, nonpolluted waterways, the lakes and tributaries that feed rivers, and areas showing little human impact (Mowbray et al., 1979; Tabor and Wight, 1977). The river otter dens in banks and hollow logs. Individuals range over large areas daily, feeding primarily on fish. Although otters have few natural predators, while on land, they may be taken by coyotes, fox, or dogs (Melquist and Hornocker, 1983). Otters clean themselves frequently by rubbing and rolling in any dry surface (Toweill and Tabor, 1982). Otters appear to undergo bradycardia while submerged and can stay underwater for up to 4 minutes (Melquist and Dronkert, 1987).

Home Range

The river otter's home range encompasses the area needed for foraging and reproduction (Melquist and Dronkert, 1987). The shape of the home range varies by habitat type; for example, near rivers or coastal areas, it may be a long strip along the shoreline (measured in kilometers), but in marshes or areas with many small streams, the home range may resemble a polygon (measured in hectares; Melquist and Dronkert, 1987). All parts of a home range are not used equally; instead, several activity centers may be interconnected by a stream or coast (Melquist and Hornocker, 1983). Food has the greatest influence on habitat use, but adequate shelter in the form of temporary dens and resting sites also plays a role (Anderson and Woolf, 1987a; Melquist and Hornocker, 1983). River otters use dens dug by other animals or natural shelters such as hollow logs, logjams, or drift piles (Toweill and Tabor, 1982; Melquist and Dronkert, 1987). Beaver bank dens and lodges accounted for 38 percent of resting sites used by radio-tracked otters in Idaho (Melquist and Hornocker, 1983). River otters appear to prefer flowing water habitats (e. g., streams) over more stationary water (e. g., lakes, ponds) (Idaho study; Melquist and Hornocker, 1983). River otters maintain distinct territories within their home ranges: females maintain a feeding area for their families, males for breeding purposes (Toweill and Tabor, 1982). Individuals tend to avoid confrontation through mutual avoidance (Melquist and Hornocker, 1983). Home ranges are most restricted for lactating females (Melquist and Dronkert, 1987).

In marshes and streams of Missouri, home ranges of adults can be anywhere from 400 to 1900 ha (Erickson et al., 1984) compared to a range of 2,900 to 5,700 ha during the fall and spring in Colorado (Mack, 1985). Conversely, river otters in west central Idaho had home ranges of 28 ± 7.5 SD km (range 15-39 km) (Melquist and Hornocker, 1983). Adult and subadult males have larger, more variable home ranges than females. Adult males in coastal marshes of Texas had home ranges of 400 ha, while adult females had ranges of only 295 ha (Foy, 1984). In river drainages of Idaho, male yearlings had home ranges of 43 ± 20 SD km (range 10-78 km) and yearling females had home ranges of 32 ± 6.2 SD km (range 25-40 km) (Melquist and Hornocker, 1983). In comparison, adult females had a home range of 31 ± 9.2 SD km (range 23-50 km).

Population Density

River otter populations show variable spacing in relation to prey density and habitat (Hornocker et al., 1983). This characteristic, along with their secretive habits and use of several den sites, makes it difficult to estimate river otter populations (Melquist and Dronkert, 1987). Population density of otters often is expressed in terms of number per km of waterway or coastline because of their dependence on aquatic habitats. Densities between one otter every km to one otter every 10 km of river or shoreline are typical. River otters have higher densities in Alaska and Idaho, than Texas and Missouri (Melquist and Hornocker, 1983; Woolington, 1984; Foy, 1984; and Erickson et al., 1984). River otters in Idaho rivers average 0.26 otters/km (range 0.17 to 0.37) (Melquist and Hornocker, 1983), while those found along coastal islands of Alaska average 0.85 otters/km (Woolington, 1984). Coastal marshes of Texas range from 0.0094 to 0.014 otters/ha (Foy, 1984). Breeding males and females of marshes and streams in Missouri had population densities of 0.0025 otter/ha (Erickson et al., 1984). Adult females in Idaho have population densities of 0.05 otters/km, while those of adult males are 0.019 otters/km (Melquist and Hornocker, 1983). Yearlings had population densities of 0.071 otters/km.

Population Dynamics/Survival

Otters generally are not sexually mature until 2 years of age (Liers, 1951b; Hamilton and Eadie, 1964; Tabor and Wight, 1977; Lauhachinda, 1978). Adult females appear to reproduce yearly in Oregon (based on a pregnancy rate of almost 100 percent; Tabor and Wight, 1977), but Lauhachinda (1978) concluded that they breed every other year in Alabama and Georgia. Peak dispersal of young occurs from April to May in Idaho (Melquist and Hornocker, 1983). In Oregon, mortality rates are 27 percent for otters between the ages of 2 and 11(Tabor and Wright, 1977). The highest mortality rate occurred in the age range of 1-2 years and was 54 percent. Between birth and one year old the mortality rate was 32 percent. In Alabama, adult males had mortality rates of 17.8 percent and females had a rate of 20.3 percent(Lauchachinda, 1978). As adults, river otter mortality rates are low, between 15 and 30 percent per year (Lauhachinda, 1978; Tabor and Wight, 1977). In Alabama and Georgia, river otters were reported to live less than 15 years (Lauhachinda, 1978).

Reproduction/Breeding

River otters breed in late winter or early spring over a period of 3 months or more (Hooper and Ostenson, 1949; Hamilton and Eadie, 1964; Lauhachinda, 1978). Birth of a litter follows mating by about 1 year; however, implantation is delayed for approximately 10 months, and active gestation lasts only 2 months (Pearson and Enders, 1944 cited in Toweill and Tabor, 1982; Melquist and Dronkert, 1987). Lancia and Hair (1983) give a mean of 60-63 days. Captive otters in Wisconsin had a total gestation time of 290 to 380 days (Liers, 1951b). Parturition begins in mid-March and lasts until mid-May in the Chesapeake Bay area of Maryland (Mowbray et al., 1979), late-March to early April in Idaho (Melquist and Hornocker, 1983), and late January to May in Alabama (Lauhachinda, 1978). Newborn otters are born blind but fully furred and depend on their mother for milk until 3 to 5 months of age (Johnstone, 1978; Liers, 1951b, Harris, 1968).

Litters usually consist of two to three pups, although litters as large as six pups occur. In Maryland wetlands, litter sizes are between 1 and 4 (mean 2.73 ± 0.77 SD) (Mowbray et al., 1979). In Georgia and Alabama litter sizes are also between 1 and 4 with the mean being 2.68 ± 0.71 SD (Hill and Lauhachinda, 1981). In New York the mean litter size is 2.1 ± 0.7 SD (Hamilton and Eadie 1964). Docktor et al. (1987) observed differences in litter size with age of female, with females 1, 2, 3, 4, and 5-12 years old having litter sizes of 0.53 ± 0.91 SD, 0.87 ± 0.96 SD, 1.6 ± 1.42 SD, 2.29 ± 1.25 SD, and 2.67 ± 1.40 SD, respectively.

Behavior and Social Organization

Adult males are usually solitary, while an adult female and two or three pups make up a typical family group (Melquist and Dronkert, 1987). Family groups disperse about 3 months after the pups are weaned (Melquist and Hornocker, 1983).

Seasonal patterns in otters are not well understood. However, otters are active throughout the year (Toweill and Tabor, 1982), with the most intense activity levels during the winter (Larsen, 1983; Melquist and Hornocker, 1983). They undergo a gradual molt in spring and fall (Melquist and Dronkert, 1987).

3.2.10 Weasels (*Mustela spp.*)[2]

Weasels are in the order Carnivora, family Mustelidae. Weasels are small to medium sized predators with a characteristic elongated body form. Three species occur in North America, the long-tailed weasel (*Mustela frenata*), the short-tailed weasel (ermine or stoat; *M. erminea*), and the least weasel (*M. nivalis)* (Svendsen, 1982). Additional *Mustela* species in North America include the mink (*M. vison*) and the black-footed ferret (*M. nigripes*). Because exposure parameters for mink are presented in EPA (1993) and the black-footed ferret is a critically endangered species with an extremely limited distribution, neither species is discussed here.

Distribution

Long-tailed weasels occur from southern Canada, throughout the United States (except for the desert Southwest), through Central America to northern South America (Svendsen, 1982). Both short-tailed and least weasels have circumpolar ranges, occurring throughout the Holarctic (King, 1983, Svendsen, 1982). In North America, short-tailed weasels occur across the Arctic, south to northern California, Nevada, Utah and Colorado in the west and south to northern Iowa, Wisconsin, Michigan and Pennsylvania in the east (Svendsen, 1982, Burt and Grossenheider, 1976). Least weasels occur from Alaska and the Canadian Arctic, south to Nebraska, Iowa, Illinois, Indiana, Ohio, and Pennsylvania to the southern Appalachians (Svendsen, 1982, Burt and Grossenheider, 1976). Least weasels are not known to occur in the Rocky Mountains or in northern New England. The northern distribution of long-tailed weasels in North America may be limited by snow cover which restricts foraging (Simms, 1979a). Southern distribution of least and short-tailed weasels may be limited by competition and interference interactions with long-tailed weasels (Simms, 1979a).

Body Size and Weight

Of the three North American weasels, the long-tailed weasel is the largest (total length: 300-350 mm), short-tailed weasels are intermediate in size (total length: 225 - 340 mm) , and least weasels are smallest (total length: <250 mm in males; <225 mm in females) (Svendsen, 1982). Tail length is 40-70 percent of head and body length for long-tailed weasels, 30-45 percent for short-tailed weasels, and 25 percent or less for least weasels (Svendsen, 1982). While both long-tailed and short-tailed weasels have black-tipped tails, the least weasel does not. Summer pelage of these three species is generally brown on top and white to yellowish on the undersides. Winter coats are generally a uniform white.

Sexual dimorphism is pronounced in weasels, with males consistently larger than females. Sexual dimorphism is attributed to the polygynous mating system of weasels; small females have an energetic advantage over large females while rearing young while large males have a competitive advantage during breeding (Erlinge, 1979, Moors, 1980). Body weights of weasels from several locations are summarized in Table 3-21. Sanderson (1949) presents data on growth of a litter of long-tailed weasels from 35 to 100 days in age. Growth curves for male and female least weasels maintained in captivity for 15 weeks are presented by Heidt et al. (1968).

[2] Text directly from Sample et al. (1997a).

TABLE 3-21
Body Weights (kg) for the Weasels

Species	Location	Sex	N	Mean	Range	Reference
Long-tailed weasel	Nevada	Male: adult	4	0.297±0.036[a]		Brown and Lasiewski, 1972
		Female: adult	4	0.153±0.003[a]		
	Montana	Male: adult	12	0.287		Wright, 1947
	Indiana	Male: adult	19	0.200±0.054[a]	0.102-0.284	Mumford and Whitaker, 1982
		Female: adult	6	0.094±0.010[a]	0.083-0.109	
	North America	Male: adult			0.198-0.340	Burt and Grossenheider, 1976
		Female: adult			0.085-0.198	
Short-tailed weasel	New Zealand[c]	Male: adult	11	0.308±0.016[b]		King et al., 1996
		Female: adult	8	0.209±0.013[b]		
	Europe	Male: adult			0.208-0.283	King, 1983
	Great Britain	Male: adult		0.320		
	Russia	Male: adult			0.134-0.191	
	North America	Male: adult			0.056-0.206	
	Minnesota	Male: adult	12		0.090-0.170	Jones et al., 1983
		Female: adult	4		0.043-0.071	
	Colorado	Female: adult	4	0.038	0.030-0.044	
	North America	Male: adult			0.071-0.170	Burt and Grossenheider, 1976
		Female: adult			0.028-0.085	
Least weasel	Indiana	Male: adult	26	0.045±0.013[a]	0.026-0.068	Mumford and Whitaker, 1982
		Female: adult	10	0.032±0.090[a]	0.022-0.052	
	Great Plains,	Male: adult	2		0.055-0.063	Jones et al., 1983
	North America	Female: adult	5	0.042	0.032-0.050	
	North America	Male: adult			0.039-0.063	Burt and Grossenheider, 1976
		Female: adult			0.038-0.039	

[a] Mean ± STD
[b] Mean ± SE
[c] Individuals introduced from Great Britain

Food Habits and Diet Composition

Weasels are specialist predators of small, warm-blooded vertebrates (King, 1983). Their diet consists predominantly of small mammals (50-80 percent of annual consumption) with larger species consuming larger-sized prey (Table 3-22; Svendsen, 1982). Other foods may be consumed, depending on season and availability. Food preferences of weasels from several locations are listed in Table 3-22.

TABLE 3-22
Diet Composition of Weasels

Species	Location	Prey Taxon	Percent	Comments	Reference
Long-tailed weasel	Michigan	Small mammals		Data represent frequency of occurrence of prey types in 294 scats from winter.	Quick, 1944
		Peromyscus	98.3		
		Microtus	28.2		
		Tamiasciurus	1.0		
		Small birds	6.8		
	Colorado	Small mammals		Data represent frequency of	Quick, 1951

TABLE 3-22
Diet Composition of Weasels

Species	Location	Prey Taxon	Percent	Comments	Reference
		Microtus	52.0	occurrence of prey types in 77 scats from all seasons.	
		Peromyscus	19.5		
		Eutamias	18.2		
		Cynomys	2.6		
		Thomomys	3.9		
		Cittelus	2.6		
		Ochatona	1.3		
		Insects			
		Vespula	6.5		
		Tettigoniidae	2.6		
	Iowa	*Microtus*	42.85	Data represent percent volume of prey types in 135 scats from winter and spring.	Polderboer et al., 1941
		Reithrodontomys	21.75		
		Peromyscus	10.23		
		Sylvilagus floridanus	8.42		
		Blarina	5.42		
		Mus	1.86		
		Tree Sparrow	1.02		
		Grasshopper	0.60		
		Geomys	0.60		
		Mustela nivalis	5.40		
		Unidentified matter	1.85		
	California	*Microtus*	97.9	Data represent percent occurrence of prey remains by dens in winter.	Fitzgerald, 1977
		Thomomys	1.0		
		Peromyscus	0.5		
		Sorex	0.5		
Short-tailed weasels	California	*Microtus*	99.1	Data represent percent occurrence of prey remains by dens in winter.	Fitzgerald, 1977
		Peromyscus	0.2		
		Sorex	0.35		
		Small birds	0.35		
	Minnesota	Mice	54.5	Data represent percent volume of prey types in 80 stomachs in winter.	Aldous and Manweiler, 1942
		Shrews	21.8		
		Hare	6.1		

TABLE 3-22
Diet Composition of Weasels

Species	Location	Prey Taxon	Percent	Comments	Reference
		Porcupine	5.0		
		Birds	2.7		
		Weasel	2.5		
		Squirrel	2.5		
		Fish	1.2		
		Unknown	3.7		
	Great Britain	Mammals			King and Moors, 1979
		Mice and Voles	22.0		
		Rats and Squirrels	4.8		
		Insectivores	0.6		
		Lagomorphs	28.0		
		Birds	33.3		
		Invertebrates	4.2		
Least Weasels	Great Britain	Mammals			King and Moors, 1979
		Mice and Voles	55.3		
		Rats and Squirrels	2.6		
		Insectivores	1.3		
		Lagomorphs	19.1		
		Birds	14.5		
		Invertebrates	5.3		
	Great Britain	Small rodents	89	Data represent frequency of occurrence of prey types in 215 scats.	King, 1980
		Voles	67		
		Cleithrionomys	41		
		Microtus	19		
		Unidentified vole	7		
		Mice (*Apodemus*)	16		
		Unidentified rodents	7		
		Birds	23		
		Passerines	12		
		Non-passerines	2		
		Unidentified birds	3		
		Eggs	7		

TABLE 3-22
Diet Composition of Weasels

Species	Location	Prey Taxon	Percent	Comments	Reference
		Lagomorph	0.5		
		Mole	0.5		
	Sweden	*Microtus*	46	Data represent frequency of occurrence of prey types in 148 scats.	Erlinge, 1975
		Cleithrionomys	9		
		Apodemus	10		
		Arvicola	16		
		Lagomorph	15		
		Soricidae	1		
		Birds	2		
		Reptile	1		

Food Consumption Rate

Observations of three long-tailed weasels (sex not reported) indicate that four mice/day would "sustain them in apparent health" (Quick, 1951). Brown and Lasiewski (1972) report the mean (±STD) metabolism of male and female long-tailed weasels to be 1.36 ±0.2 and 0.84 ±0.12 kcal/hr, respectively. Assuming that male and female weasels weigh 0.297 kg and 0.153 kg (Brown and Lasiewski, 1972), respectively, the diet consists exclusively of small mammals with an energy content of 5163 kcal/kg dry weight (Golley, 1961), and the water content of small mammals is 68 percent (Table 3-4), male and female weasels consume 0.067 and 0.080 kg food/kg BW/d. For comparison, food ingestion by male and female long-tailed weasels, estimated using Eq. 5 is 0.266 and 0.299 kg food/kg BW/d, respectively [assuming BW from Brown and Lasiewski (1972), diet consisting only of small mammals, and water content of small mammals is 68 percent (Table 3-4)].

No data were found concerning food ingestion by short-tailed weasels. Using Eq. 5 and assuming body weights for males and females reported by Burt and Grossenheider (1976; Table 23), a diet consisting only of small mammals with water content 68 percent (Table 3-4), food ingestion rates of 0.29 to 0.34 kg food/kg BW/d are estimated for males and 0.33 to 0.41 kg food/kg BW/d for females.

Food ingestion by least weasels has received more attention than that for other weasels. Golley (1960) observed food consumption of 0.41 and 0.42 kg/kg/d for a single least weasel (assumed to weigh 0.36 kg) on a diet of *Microtus* or white mice (*Mus*), respectively. Moors (1977) observed mean (± STD) food ingestion by male and female least weasels to be 0.33 ± 0.06 and 0.36 ± 0.08 kg/kg/d, respectively. The greatest food ingestion rates are reported by Gillingham (1984); mean (± STD) ingestion by six individuals (sex not reported) was 0.56 ± 0.03 kg/kg/d.

Water Consumption Rate

Weasels require a constant supply of drinking water, drinking small amounts frequently (Svendsen, 1982). Long-tailed weasels are reported to consume 25 mL water/d (Svendsen, 1982). No other literature data were found describing water ingestion by weasels. Using Eq. 19, water ingestion rates may range from 0.11 L/kg BW/d for long-tailed weasels weighing 0.297 kg to 0.15 L/kg BW/d for least weasels weighing 0.022 kg. If other body weight values are used, the water ingestion rate should be recalculated.

Soil Ingestion

No literature data were found describing soil ingestion by any weasel species. Beyer et al. (1994) report soil consumption by red fox to be 2.8 percent of daily food consumption. Values for weasels may be comparable.

Respiration Rate

No literature data were found describing inhalation by weasels. Using Eq. 21, inhalation rates may range from 0.70 m^3/kg BW/d for long-tailed weasels weighing 0.297 kg to 1.17 m^3/kg BW/d for least weasels weighing 0.022 kg. If other body weight values are used, the inhalation rate should be recalculated.

Metabolism

Brown and Lasiewski (1972) found that cold-stressed long-tailed weasels lost body heat more rapidly and had metabolic rates 50-100 percent greater than would be expected for a 'normal' shaped animal of similar weight. Higher metabolic rates and greater thermal conductance for weasels relative to other mammals are also reported by Casey and Casey (1979) and Chappell (1980). Similarly, Iversen (1972) observed that the basal metabolic rate of small mustelids (<1 kg BW, includes both short-tailed and least weasels) was greater than that for larger mustelids (>1 kg BW). Metabolism for small mustelids was described by the following equation:

$$M = 0.958BW^{0.55} \tag{53}$$

where

M = basal metabolic rate (kcal/d)

BW = body weight (kg)

The higher metabolic rates and thermal conductance of weasels are attributed to greater surface area, shorter fur, and the inability of weasels to attain a spherical posture that would reduce heat loss (Brown and Lasiewski, 1972).

Habitat Requirements

Habitat preferences of weasels are highly variable. All species tend to be most abundant in habitats with large small mammal populations and near bodies of water. Quick (1944) observed that long-tailed weasels in Michigan spent 53 percent of their time in crop and fallow land, 29 percent in plowed fields, and 18 percent in forested areas. Stubble and plowed fields appeared to be preferred hunting areas. Similar observations were made by Polderboer et al. (1941). In contrast, Gamble (1981) found that long-tailed weasels preferred late seral stage habitats where prey species diversity was greatest. In southern Ontario, long-tailed weasels used habitats ranging from grassland to forest, with no apparent preference (Simms, 1979b).

Short-tailed weasels occur from agricultural lowlands, woodlands, and meadows to montane habitats 3,000 - 4,000 m in elevation; dense forests and deserts are avoided (Svendsen, 1982). In southern Ontario, short-tailed weasels were observed to prefer early successional habitats and avoid forests (Simms, 1979b).

Habitats used by least weasels include marshes, meadows, cultivated fields, brushy areas, and open woods (Svendsen, 1982). In Wisconsin, high marsh habitats with the water table at or near the surface for a good part of the year are preferred (Beer, 1950a). Erlinge (1974) observed spruce plantations and regenerating clearings to be most preferred by least weasels.

Home Range

Home ranges of weasels vary by sex, habitat, food availability and season, with smaller species having smaller home ranges (Svendsen, 1982). King (1975) reports home ranges for least weasels in a deciduous forest in Great Britain to be 7-15 ha for males and 1-4 ha for females. In the Bialowieza Forest of eastern Poland, home ranges for male least weasels increased from 11-37 ha during a rodent outbreak to 117-216 ha during a rodent population crash (Jedrzejewski et al.1995). Erlinge (1977) reports home ranges for male and female short-tailed weasels in Sweden to be 2-3 ha and 8-13 ha, respectively. In contrast, home ranges for short-tailed weasels in Ontario ranged from 20-25 ha and 10-15 ha for males and females, respectively (Simms, 1979b). Home ranges for long-tailed weasels have been reported to range from 5-16 ha in Iowa (Polderboer et al., 1941) to 81-121 ha in Michigan and Colorado (Quick, 1944, 1951).

Population Density

Weasel population densities vary considerably by season, food availability, and species (Svendsen, 1982). For example, densities of least weasels in the Bialowieza Forest of eastern Poland range from 0.52 to 2.73 individuals/km^2 in winter, declining to 0 to 1.9 individuals/km^2 in early spring (Jedrzejewski et al.1995). Midsummer densities varied from 4.2 to 4.8 individuals/km^2 in years of moderate prey abundance, to 10.2 individuals/km^2 during a rodent population peak, to 1.9 individuals/km^2 during the prey population crash. In a study of a 95 ha area in southern Ontario comprised predominantly of early successional habitat, Simms (1979b) observed an overall density of short-tailed weasels of 5.97 individuals/km^2. However, if only preferred habitat types are considered, density is 10.53 individuals/km^2. Svendsen (1982) reports that densities of long-tailed weasels may range from 6 to 7 individuals/km^2, while in the Rocky Mountains of Colorado, 0.77 individuals/km^2 are reported (Quick, 1951).

Population Dynamics/Survival

Population fluctuations of weasels are associated with the abundance of prey species. Keith and Cary (1991) observed that 81 percent of the variation in abundance of weasels (*M. frenata* and *M. erminea*) was attributed to fluctuations in the abundance of hares, voles and mice in Alberta, Canada. In the Bialowieza Forest of eastern Poland, abundance of least weasels was observed to be positively correlated with the abundance of voles and mice (Jedrzejewski et al., 1995).

Longevity of weasels is not well documented. Mean age at death for least weasels in Great Britain was 11 months (King, 1975). The lifespan for short-tailed weasels in the wild is reported to be 4 to 6 years (Svendsen, 1982). In a study of short-tailed weasels in New Zealand, the mean age of individuals captured was 15 months; maximum longevity was 5 years (King et al., 1996). Age-specific mortality of first year individuals was 76 percent. In Colorado, marked adult long-tailed weasels were observed in the same area for 3 years (Svendsen, 1982).

Reproduction/Breeding

Both long-tailed and short-tailed weasels display delayed implantation (Svendsen, 1982). Fertilized ova develop to the blastocyst stage in approximately 14 days, then remain free in the uterus for the next 9 to 10 months (King, 1983). Active gestation, from implantation of the embryo to parturition, takes approximately 4 weeks (King, 1983). The least weasel, in contrast, does not have delayed implantation; kits are born approximately 41 days following fertilization (Svendsen, 1982). Additional reproductive parameters for North American weasels are summarized in Table 3-23.

TABLE 3-23
Summary of Reproductive Characteristics for North American Weasels (data from Svendsen, 1982)

Species	Age at Sexual Maturity	Breeding Season	Gestation	Litter Size	Number Litters/Year
Long-tailed weasel	♂: 1 yr ♀: 3-4 months	July-August	~ 278 days; 27 days implantation	6-9	1
Short-tailed weasel	♂: 1 yr ♀: 3-4 months	July-August	~ 270 days; 21-28 days implantation	6-9	1
Least weasel	♂: 3-4 months ♀: 3-4 months	All year	~ 41 days; no delayed implantation	3-6	2-3

Behavior

Weasels are active year-round and do not hibernate (Svendsen, 1982). While commonly considered to be nocturnal, weasels tend to be most active during the daytime (Svendsen, 1982). Erlinge (1980) observed seasonal changes in daily activity; short-tailed weasels tended to be nocturnal in winter and diurnal in summer.

3.3.11 Harbor Seals (*Phoca vitulina*)[1]

Harbor seals are in the order Carnivora, family Phocidae. Seals, sea lions, and walruses are collectively referred to as pinnipeds (Latin for wing-footed). Pinnipeds are divided into three families: otarids (sea lions and fur seals); phocids (hair seals, also called true seals or earless seals); and walruses. Most pinnipeds feed on marine species such as fish, squid, and other invertebrates (Burt and Grossenheider, 1980). Unlike fur seals, which are protected from the cold marine environment by a dense layer of underfur, phocids rely only on a thick blubber layer for insulation (Pierotti and Pierotti, 1980). Phocids include both the smallest (ring seals) and the largest (elephant seals) of the pinnipeds. The geographic range of most phocid species is from the arctic Atlantic and Pacific south to the coasts of Canada and Alaska, although some do inhabit warmer water (Burt and Grossenheider, 1980). Most phocids, with the exception of the

[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a)

elephant seal, do not exhibit the large disparity in size between the sexes, which is characteristic of otarids (sea lions and fur seals) (Burt and Grossenheider, 1980).

Distribution

In North America, harbor seals range from Alaska to Baja California, Mexico, along the Pacific coast (subspecies richardsi; Hoover, 1988), and from Newfoundland to eastern Long Island along the Atlantic coast (subspecies concolor; Payne and Selzer, 1989). They are one of the most commonly seen pinniped species, in part due to their tendency to inhabit coastal areas (Hoover, 1988). Harbor seals can be found along the Pacific coast on a year-round basis (except during stormy periods in winter), but Atlantic populations winter offshore when coastal ice has formed in their usual haul-out areas (Boulva and McLaren, 1979). The recent increases in harbor seal populations in New England waters appear to be due to a southward dispersal of seals from rookeries in Maine following the termination of a Massachusetts bounty on harbor seals (1962) and the passage of the Marine Mammal Protection Act (1972) (Payne and Schneider, 1984).

Body Size and Weight

The length and weight of harbor seals vary geographically, but sexually mature adults tend to be about 1.5 m in length and weigh from 65 to 90 kg (Ashwell-Erickson and Elsner, 1981; Pitcher and Calkins, 1979). Harbor seals exhibit some sexual dimorphism, the male being larger (Pitcher and Calkins, 1979). Body length usually is used to measure size because weight can vary substantially with factors such as season, food availability, and molting (Ronald et al., 1982). Newborn pups are around 80 cm long and weigh from 8.6 to almost 15 kg, with females often weighing less than males (Newby, 1973; Pitcher and Calkins, 1979; Rosen, 1989). Harbor seal pups are highly precocial and are able to swim within hours of birth (Boulva and McLaren, 1979; Lawson and Renouf, 1987). Seal milk consists of about half fat, and the pups more than double their weight before they are weaned at approximately 30 days (Bigg, 1969a, as cited in Pitcher and Calkins, 1979). Harbor seals continue to grow with age for several years beyond the age of sexual maturity (Boulva and McLaren, 1979; Pitcher and Calkins, 1979). Body fat varies seasonally with food intake, while total body weight and lean body mass increase with age (Ashwell-Erickson and Elsner, 1981). Harbor seals, unlike many other pinnipeds, do not fast for extended periods during the molting period or breeding season (Boulva and McLaren, 1979; Pierotti and Pierotti, 1980).

Food Habits and Diet Composition

Harbor seals' diet varies seasonally and includes bottom-dwelling fishes (e. g., flounder, sole, eelpout), invertebrates (e. g., octopus), and species that can be caught in periodic spawning aggregations (e. g., herring, lance, squid) (Everitt et al., 1981; Lowry and Frost, 1981; Pitcher and Calkins, 1979; Roffe and Mate, 1984). Harbor seals are opportunistic, consuming different prey in relation to their availability and ease of capture (Pitcher and Calkins, 1979; Pitcher, 1980; Shaffer, 1989). They may move into rivers on a seasonal basis in pursuit of prey (e. g., eulachon in the Columbia River during winter; Brown et al., 1989). They hunt alone or in small groups (Hoover, 1988). Fish species consumed range between 40 and 280 mm, with mean values of between 60 and 180 mm (Brown and Mate, 1983). Studies of harbor seal diet often rely on counts of fish sagittal otoliths found in scats or stomach g contents. These otoliths can be identified to the level of species, annuli on the otoliths counted to determine age, and fish weights and lengths estimated from otolith dimensions. However, partial or complete digestion

TABLE 3-24
Body Weights (kg) of Harbor Seal (*Phoca vitulina*)

Location	Sex	N	Mean	Reference
Gulf of Alaska	Adult Male (> 7 yrs)		84.6 ± 11.3	Pitcher and Calkins, 1979
	Adult Female (>7 yrs)		76.5 ± 17.7	
Aleutian Ridge and Pribilof Islands, Bering Sea, Alaska	Juvenile Male 2 yrs		49	Ashwell-Erickson and Elsner, 1981
	Juvenile Male 4 yrs		70	
	Juvenile Male 6 yrs		84	
	Adult Male 8 yrs		95	
	Adult Male 12yrs		110	
	Adult Male 16 yrs		120	
	Adult Male 24 yrs		124	
	Juvenile Female 2 yrs		40	
	Juvenile Female 4 yrs		56	
	Juvenile Female 6 yrs		67	
	Adult Female 8 yrs		76	
	Adult Female 12yrs		90	
	Adult Female 16 yrs		101	
	Adult Female 24 yrs		112	
Alaska	neonate (male)		12.0 ± 0.51	Pitcher and Calkins, 1979
	neonate (female)		11.5 ± 0.31	
British Columbia, Canada	at weaning (both)		24.0	Bigg, 1969a

of otoliths, particularly of small fish species, may result in significant underestimates of the proportion of these prey in seal diets, particularly from scat analysis (da Silva and Neilson, 1985; Harvey, 1989). Studies of stomach contents of stranded seals also may present a biased picture of dietary composition due to extended periods of fasting prior to stranding (Selzer et al., 1986).

Recently weaned pups tend to feed on prey that are more easily captured than fish, such as shrimp or other crustaceans (Hoover, 1988; Pitcher and Calkins, 1979). During the breeding and molting seasons, when harbor seals spend more time on land, adults rely on their blubber layer as an additional source of energy (Ashwell-Erickson and Elsner, 1981). During this time, they may be more susceptible to lipophilic contaminants (e.g., PCBs) that may have accumulated in their blubber (Hoover, 1988).

TABLE 3-25
Diet Consumption of the Harbor Seal (*Phoca vitulina)*

Location/Habitat	Prey Taxon	Spring	Summer	Fall	Winter	Reference
Washington/coastal island	walleye pollock	3.7	27.3	32.2	1.3	Everitt et al., 1981
	English sole	37.0	0	27.0	0	
	shiner perch	0	0	0.5	63.6	
	Pacific herring	0	54.6	3.9	28.6	
	Pacific cod	0	0	10.1	0	(% of total otoliths recovered from scat samples)
	rex sole	37	9.1	2.9	0	
	Pacific tomcod	3.7	0	4.7	0	
	rockfish	3.7	0	4.7	0	
	Dover sole	3.7	0	3.4	2.6	
	Petrale sole	7.4	0	1.8	0	
	other fish	3.8	9.0	8.8	3.9	
Kodiak Island, Alaska/coastal marine	octopus		17.6	17.7	30.4	Pitcher and Calkins, 1979
	salmon		5.4	0	0	
	capelin		20.3	4.8	5.4	(% frequency of occurrence; stomach contents)
	Pacific cod		6.8	8.1	10.7	
	walleye pollock		12.2	9.7	14.3	
	Pacific sandlance		4.1	21.0	0	
Gulf of Alaska/coastal marine	squid and octopus		20*			Pitcher, 1980
	shrimp, crabs		3.7*			
	herring		6.4*			(percent wet volume; stomach contents)
	salmonids		4.4*			
	osmerids		22.5*			
	cod, tomcod, walleye, pollock		26*			*all seasons combined
	other		14*			

Food Consumption Rate

In general, food consumption by adult seals is highest in winter and lowest in the summer (Ashwell-Erickson and Elsner, 1981; Ashwell-Erickson et al., 1979). Innes et al. (1987) estimated allometric equations for maintenance food ingestion rates (IR; wet-weight biomass) with body weight (BW, kg) for phocids:

IR_{maint} (kg/day) = 0.079 BW(kg)$^{0.71}$ adult (N = 11; r^2= 0. 84);

IR_{maint} (kg/day) = 0.032 BW(kg)$^{1.00}$ juveniles (N = 19; r^2 = 0.68); and

IR_{maint} (kg/day) = 0.068 BW(kg)$^{0.78}$ both adults and juveniles (N = 30; r^2 = 0.68).

Allometric equations for food ingestion rates of growing animals (IR; wet-weight biomass) with body weight (BW, kg) for phocids also have been estimated (Innes et al., 1987):

IR_{growth} (kg/day) = 0.0919 BW(kg)$^{0.84}$ adult (N = 11; r^2 = 0. 84); and

IR_{growth} (kg/day) = 0.0547 BW(kg)$^{0.84}$ juveniles (N = 19; r^2 = 0.68).

Innes et al. (1987) found that growing juvenile phocid seals ingested 1.7 times more biomass per day than a similar-sized growing adult and 1. 4 times more than juvenile phocids that were not growing.

Boulva and McLaren (1979) estimated a relationship between body weight and daily food ingestion for harbor seals from eastern Canada:

$IR_{free\text{-}living}$ (kg/day) = 0.089 BW(kg)$^{0.76}$ adults (N = 26).

Perez (1990) estimated the average energy value of the harbor seal's diet to be 1.4 kcal/g wet weight. Ashwell-Erickson and Elsner (1981) provide age-specific estimates of food ingestion rates for the closely related spotted seal and summarize studies in which food ingestion rates for harbor and spotted seals have been estimated. Using Eq. 5 and assuming a body weight of 98.9 kg (as calculated from above table using adults) a food consumption rate of 0.03 kg/kg BW/day DW can be estimated. To obtain a fresh weight food ingestion rate (0.12 kg/kgBW/day), a diet of 100 percent fish (Everitt et al., 1981) with a water content of 75 percent (Table 3-4) was assumed.

Water Consumption Rate

Depocas et al. (1971) found that adult harbor seals ingested 0.0048 L/kg BW/day (Range 0.0028-0.0091) seawater, but most water was obtained from food. The estimated water consumption rate for adults of both sexes is 0.064 L/kg BW/day, based on Eq. 19 using body weights from Pitcher and Calkins (1979). This estimation should be used cautiously, however, because pinnipeds were not included in the data set from which the allometric model was derived. (Note: If using different body weights, then the rate should be recalculated.)

Soil Ingestion

No soil ingestion data was available in the literature reviewed. Although no comparable data is available from known sources (e.g., Beyer et al., 1994), soil ingestion is likely to be high for harbor seals because they primarily feed on bottom-dwelling fish and invertebrates (Everitt et al., 1981; Pitcher and Calkins, 1979; Pitcher, 1980)

Respiration Rate

No literature data were available for respiration rates in harbor seals. Therefore, inhalation rates of 0.22 m^3/kg BW/day for males and 23.0 m^3/kg BW/day for females were estimated using Eq. 21 and body weights from Pitcher and Calkins (1979). This estimation should be used cautiously, however, because pinnipeds were not included in the data set from which the allometric model was derived. (Note: If different body weights are used, then the rate should be recalculated.)

Metabolism

Ashwell-Erickson and Elsner (1981) report the average metabolic rate of harbor seals in the Bering Sea off the coast of Alaska to be 57.5 kcal/kg-day. Modeled estimates are over twice as high with free living females having a metabolic rate of 131 kcal/kg-day (range 57-300) and free living males at 129 kcal/kg-day (range 56-296), based on the equation in Nagy (1987) using body weights from Pitcher and Calkins (1979). Adult basal metabolic rate was estimated at 24.3 and 22.4 Kcal/kg-day for females and males respectively based on the equation in Boddington (1978) and body weights from Pitcher and Calkins (1979). These estimations should be used cautiously, however, because pinnipeds were not included in the data sets from which the allometric models were derived.

Harbor seals can maintain their heat balance while diving in water as low as 13°C without increased muscle activity or metabolic rate (Ronald et al., 1982). For seals in general, molting is simply part of an ongoing pelage cycle that is influenced by the seal's environment, physiology, and behavior (Ling, 1974). Phocids get an entirely new coat with each annual molt (Ling, 1970), a process that takes about 5 weeks (Scheffer and Slipp, 1944, as cited in Ashwell-Erickson and Elsner, 1981). During their molt, they spend more time hauled and exhibit a slower metabolic rate (e. g., 83 percent of premolt levels), which decreases their food requirements (Ashwell-Erickson and Elsner, 1981). After molting, harbor seals increase their fat reserves (and weight) for the winter and early spring; metabolic rates also might be lowered during this time to conserve energy (Renouf, 1989).

Habitat Requirements

Harbor seals inhabit a variety of environments and are able to tolerate a wide range of temperatures and water salinities (Boulva and McLaren, 1979; Hoover, 1988). In its eastern range, the harbor seal inhabits inlets, islets, reefs, and sandbars (Boulva and McLaren, 1979). In western North America, the harbor seal inhabits tidal mud flats, sand bars, shoals, river deltas, estuaries, bays, coastal rocks, and offshore islets (Johnson and Jeffries, 1977), even ranging up rivers into freshwater areas in search of food (Roffe and Mate, 1984). Harbor seals also inhabit some freshwater lakes (Power and Gregoire, 1978). Habitats used for haul-outs include cobble and sand beaches, tidal mud flats, offshore rocks and reefs, glacial and sea ice, and man-made objects such as piers and log booms (Hoover, 1988).

Home Range

Harbor seals generally inhabit highly productive coastal areas, with upwelling ocean currents that bring nutrients to the surface supporting abundant marine life (e. g., the California current system, the Gulf of Alaska, and the Gulf of Maine; Ronald et al., 1982). Harbor seals also require adequate places to haul out, and their distribution is influenced by the availability of suitable sites (Boulva and McLaren, 1979). In general, seals stay near particular haul-out sites with only local movements (Brown and Mate, 1983; Pitcher and Calkins, 1979; Slater and Markowitz, 1983). Haul-out patterns are determined by several factors, including weather, tidal pattern, time of day, season, and human proximity (Slater and Markowitz, 1983). Harbor seals are considered fairly sedentary, with individuals showing year-round site fidelity, although some seasonal movement associated with pupping and long-distance movements are recorded (Pitcher and Calkins, 1979; Slater and Markowitz, 1983). A foraging radius for harbor seals was estimated by both Stewart et al. (1989) and Beach et al. (1985). Stewart et al (1989) reported a foraging radius of 5 km for adults in a California bay while Beach et al. (1985) estimated a foraging range of 30 to 55 km near the Columbia River in Washington.

Population Density

Harbor seals are found principally in coastal areas within 20 km of shore; they tend to concentrate in estuaries and protected waters (Hoover, 1988). Their distribution is highly patchy, and local population densities in haul-out areas with favorable food resources nearby can be quite high (Pitcher and Calkins, 1979). Estimates of summer population density along the coast of Maine were 0.00394 to 0.0611 seals/ha (Richardson, 1981).

Population Dynamics/Survival

Females are sexually mature by 3 to 5 years of age, whereas males are sexually mature later, at 4 to 6 years of age (Boulva and McLaren, 1979; Pitcher and Calkins, 1979). Females only produce one pup per year (Hoover, 1988). Three major causes of preweaning pup mortality are stillbirth, desertion by the mother, and shark kills (Boulva and McLaren, 1979). Mortality from birth to 4 years of age was estimated to be 74 percent for females and 79 percent for males in one study, after which it remained at about 10 percent per year (Pitcher and Calkins, 1979). In Canada, Boulva and McLaren (1979) estimated annual mortality rates for adults to be 17.5 percent. Life expectancy for harbor seals is about 30 years (Newby, 1978). Pitcher and Calkins (1979) estimated longevity to be less than 26 years for males and less than 31 years for females in the Gulf of Alaska.

Reproduction/Breeding

The timing of reproduction in harbor seals varies with location. Mating and pupping are initiated earlier in the year in more southern latitudes, but within populations, breeding is synchronized (Hoover, 1988; Slater and Markowitz, 1983). Harbor seals may form large breeding aggregations on land in areas where food resources are plentiful (Slater and Markowitz, 1983); however, pupping activities are not restricted to large, discrete rookeries (Pitcher and Calkins, 1979). Mating occurs soon after weaning, which is 3 to 6 weeks after birth (Ashwell-Erickson and Elsner, 1981). It is likely that harbor seals are promiscuous (Pierotti and Pierotti, 1980), although there is some evidence that they are mildly polygynous, with males defending territories at the haul-out sites (Boulva and McLaren, 1979; Perry, 1989; Slater and Markowitz, 1983). Following mating, implantation is delayed for 1.5 to 3 months, during which time the female molts (Bigg, 1969a; Hoover, 1988; Pitcher and Calkins, 1979). Gestation lasts for 10.5 to 11 months (FAO Adv. Comm., 1976). Harbor seals only have one litter per year and the size is just one pup throughout their range (Hoover, 1988).

Behavior and Social Organization

At various non-breeding times of the year, harbor seals can be found in groups of 30 to 80 in some haul-out areas (Hoover, 1988).

3.2.12 Raccoon (*Procyon lotor*)[1]

The raccoon is in the order Carnivora, family Procyonidae. Procyonids are medium-sized omnivores that range throughout much of North America. The raccoon is the most abundant

[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

and widespread medium-sized omnivore in the North America. Raccoons, feed on insects, small mammals, birds, lizards, and fruits.

Distribution

They are found throughout Mexico, Central America, the United States, except at the higher elevations of the Rocky Mountains, and into southern Canada (Kaufmann, 1982). In suburban areas, they frequently raid garbage cans and dumps. Twenty-five subspecies are recognized in the United States and Canada; however, most researchers do not identify the subspecies studied because different subspecies inhabit essentially nonoverlapping geographic ranges.

Body Size and Weight

Raccoons measure from 46 to 71 cm with a 20 to 30 cm tail. Body weights vary by location, age, and sex from 3 to 9 kg (Kaufmann, 1982; Sanderson, 1987). The largest raccoons recorded are from Idaho and nearby states, while the smallest reside in the Florida Keys (Lotze and Anderson, 1979). Juveniles do not reach adult size until at least the end of their second year (Stuewer, 1943b). In the autumn, fat reserves account for 20 to 30 percent or more of the raccoon's weight (Whitney and Underwood, 1952, cited in Kaufmann, 1982). In Minnesota, Mech et al. (1968) found that juveniles gained weight almost linearly until mid-November, after which they began to lose weight until April. Weight loss in adults and yearlings can reach 50 percent during the 4 months of winter dormancy (e. g., 4.3-kg loss for a 9.1-kg raccoon) (Thorkelson and Maxwell, 1974; Mech et al., 1968). In Alabama, where raccoons are active all year, winter weight losses are less, 16 to 17 percent on average (Johnson, 1970).

TABLE 3-26
Body Weights (kg) for the Raccoon (*Procyon lotor*)

Location	Sex	N	Mean	Range	Reference
Illinois	Male		7.6	7.0-8.3	Sanderson, 1984
	Female(parous)		6.4	5.6-7.1	
	Female (nulliparous)		6.0	5.1-7.1	
	Male(juvenile)		5.1	4.6-5.7	
	Female(juvenile)		4.8	4.2-5.3	
Missouri	Male		6.76		Nagel, 1943
	Female		5.74		
Alabama	Male		4.31	Up to 8.8	Johnson, 1970
	Female		3.67	Up to 5.9	
New York (captive)	Neonate		0.075		Hamilton, 1936

Food Habits and Diet Composition

The raccoon is an omnivorous and opportunistic feeder. Although primarily active from sunset to sunrise (Kaufmann, 1982; Stuewer, 1943a), raccoons will change their activity period to accommodate the availability of food and water (Sanderson, 1987). For example, salt marsh raccoons may become active during the day to take advantage of low tide (Ivey, 1948, cited in Sanderson, 1987). Raccoons feed primarily on fleshy fruits, nuts, acorns, and corn (Kaufmann, 1982) but also eat grains, insects, frogs, crayfish, eggs, and virtually any animal and vegetable matter (Palmer and Fowler, 1975). The proportion of different foods in their diet depends on location and season, although plants are usually a more important component of the diet. They may focus on a preferred food, such as turtle eggs, when it is available (Stuewer, 1943a). They also will feed on garbage and carrion. Typically, it is only in the spring and early summer that raccoons eat more animal than plant material. Their late summer and fall diets consist primarily of fruits. In winter, acorns tend to be the most important food, although raccoons will take any corn or fruits that are still available (Kaufmann, 1982; Stuewer, 1943a).

Raccoons are preyed on by bobcats, coyotes, foxes, and great horned owls (Kaufmann, 1982).

TABLE 3-27
Diet Consumption of Raccoon (*Procyon lotor*), % Wet Weight

Location	Prey Taxon	Spring	Summer	Fall	Winter	Reference
Maryland/	crayfish	37	8	3	9	Llewellyn and Uhler, 1952
Forested	snails	5	5	3	6	
Bottomland	insects	40	39	18	12	
	reptiles/amphibians	6	5	3	7	
	fish	3	2	trace	2	
	rodents	7	2	trace	8	
	corn	0	1	2	19	
	smilax	0	trace	trace	6	
	acorns	0	trace	5	17	
	pokeberry	0	trace	17	2	
	wild cherry	0	17	2	0	
	blackberries	0	16	trace	0	
	grapes	0	trace	23	8	
	persimmon	0	0	11	7	
Tennessee	frogs	8.1	trace	0	0	Tabatabai and Kennedy, 1988
	fish	1.2	0	0	0	
	birds	trace	0	trace	8.4	
	mammals	1.7	0	1.4	0	
	unspecified/other	7.8	6.7	1.8	7.2	
	persimmon	0	35.8	57.3	27.4	
	corn	57.6	0	10.0	25.9	
	grapes	0	trace	10.2	0.0	
	pokeberry	0	20.5	4.5	0.0	
	acorns	0	0	5.4	4.2	
	sugar hackberry	0	0	5.5	18.4	
	cherry	0	29.5	0	0.0	
	insects	22.0	3.5	2.4	trace	
	crayfish	1.6	4.0	1.5	1.4	

TABLE 3-27
Diet Consumption of Raccoon (*Procyon lotor*), % Wet Weight

Location	Prey Taxon	Spring	Summer	Fall	Winter	Reference
sw Washington Tidewater Mudflats	Mollusca (mussels and oysters)		44			Tyson, 1950
	Crustacea (shrimp and crabs)		25			
	Pisces (gogy and cabezon)		9.0			
	Annelida (marine worms)		20			
	Echiurida (worms)		1			
New York	fruits		37.9			Hamilton, 1951
	insects		8.2			
	mammals		14.3			
	grains (e.g. corn)		14.7			
	earthworms		7.2			
	amphibians		4.4			
	vegetation		6.1			
	reptiles		3.0			
	molluscs		1.9			
	birds		1.5			
	carrion		1.5			
	unspecified		0.2			

Food Consumption Rate

No data was found in the literature regarding food consumption rate. Using Eq. 5 and a mean body weight of 0.0058 kg (calculated using the above table and adults) a food consumption rate of 0.17 kg/kg BW/day was estimated. A diet of 37 percent crayfish, 5 percent snails, 6 percent reptiles/amphibians, 3 percent fish, and 7 percent rodents was assumed (Llewellyn and Uhler, 1952) with respective water contents of 74, 84, 85, 75, and 68 percent as presented in Table 3-4 to calculate fresh weight (0.42 kg/kg BW/day).

Water Consumption Rate

Using Eq. 19 and body weights from Nagel (1943) the estimated water ingestion rates for an average male raccoon is 0.082 L/kg BW/day and 0.083 L/kg BW/day for the average female. (Note: If using different body weights, then the rate should be recalculated.)

Soil Ingestion

Beyer et al. (1994) estimated a soil ingestion of 9.4 percent of the diet for the raccoon. No other literature data was found.

Respiration Rate

No literature data were available; however, an inhalation rate of 0.37 m^3/kg BW/day for males and 0.38 m^3/kg BW/day for females can be estimated using Eq. 21 and body weights from Nagel (1943). (Note: If using different body weights, then the rate should be recalculated.)

Metabolism

Laboratory studies in Ohio found the metabolic rates of both male and females to be 304 kcal/kg-day (Teubner and Barrett, 1983). Adult basal metabolism rate for males is 44.8 kcal/kg-day and 46.8 kcal/kg-day for females, estimated using the equation in Boddington (1978) and body weights from Nagel (1943). Metabolic rates for free living adults are 183 and 187 kcal/kg-day for males and females respectively, estimated from the equation in Nagy (1987) based on body weights from Nagel (1943). At the National Zoo in Washington DC, during the winter the metabolic rate of captive animals is 9.36 ± 1.68 L O_2/kg-day (Mugaas et al., 1984).

Habitat Requirements

Raccoons are found near virtually every aquatic habitat, particularly in hardwood swamps, mangroves, floodplain forests, and freshwater and saltwater marshes (Kaufmann, 1982). They are also common in suburban residential areas and cultivated and abandoned farmlands (Kaufmann, 1982) and may forage in farmyards (Greenwood, 1982). Stuewer (1943a) stated that a permanent water supply, tree dens, and available food are essential. Raccoons use surface waters for both drinking and foraging (Stuewer, 1943a).

Home Range

The size of a raccoon's home range depends on its sex and age, habitat, food sources, and the season (Sanderson, 1987). Values from a few hectares to more than a few thousand hectares have been reported, although home ranges of a few hundred hectares appear to be most common. In general, home ranges of males are larger than those of females, the home range of females with young is restricted, and winter ranges are smaller than ranges at other times of the year for both sexes (Sanderson, 1987). Male raccoons inhabiting the prairie pothole regions of North Dakota have a spring/summer home range of 2560 ha (Fritzell, 1978), but during winter in riparian areas of Michigan males have a range of only 204 ha (Stuewer, 1943a). Females in North Dakota have spring and summer ranges of 806 ha (Fritzell, 1978), while in winter are reduced to 108 ha (Stuewer, 1943a). On a coastal island in Georgia, home ranges of 65 ha ± 18 SE and 39 ha ± 16 SE were found for males and females, respectively (Lotze, 1979). During the winter, raccoons commonly den in hollow trees; they also use the burrows of other animals such as foxes, groundhogs, skunks, and badgers. These sites are used for sleeping during warmer periods. After wintering in one den, the female will choose a new den in which to bear her young (Kaufmann, 1982). Schneider et al. (1971) found that once the cubs leave the den, the family will not use it again that year.

Population Density

Population density depends on the quality and quantity of food resources and densities. Values between 0.005 and 1.5 raccoons per hectare have been reported, although 0.1 to 0.2 per hectare is more common. In a marsh along Lake Erie, the population density was 0.17 raccoons per ha. (Urban, 1970), whereas only 0.022 raccoons per ha were observed in marsh areas of Wisconsin (Dorney, 1954). Populations of 1.46 raccoons per hectare have been reported in residential areas of Ohio (Hoffman and Gottschang, 1977). Although raccoons may prefer tree dens over ground dens, particularly for raising young (Stuewer, 1943a), Butterfield (1954) found high raccoon densities in an area with few tree dens but numerous ground dens. During the last 50 years, raccoon populations in the United States have increased greatly (Sanderson, 1987).

Population Dynamics/Survival

Population dynamics. Males generally are not sexually mature by the time of the first regular breeding season following their birth, but they may mature later that summer or fall (Johnson, 1970; Sanderson, 1951). Females may become pregnant in their first year (Johnson, 1970; Fritzell et al., 1985). In a review of several studies, Kaufmann (1982) found that up to 60 percent of both wild and captive females mate and produce litters in their first year. In Illinois and Missouri, Fritzell et al. (1985) found pregnancy rates of yearlings from 38 to 77 percent. After their first year, almost all females breed annually (Fritzell et al., 1985). Females produce only one litter each year, and the female alone cares for the young (Sanderson, 1987; Stuewer, 1943a, 1943b). With some exceptions (Bissonnette and Csech, 1937), larger litter sizes usually occur in the raccoon's northern range (Lotze and Anderson, 1979). In bottomlands and marshes of Alabama, the litter size is only 2.43 (Johnson, 1970). Litter sizes for females 1 to 3 years old is somewhat lower at 3.4, than for raccoons 4 years old or older at 3.8 in Illinois (Fritzell et al., 1985).

Some juveniles of both sexes disperse from the areas where they were born during the fall or winter of their first year, while others stay and raise young within their parents' home range (Stuewer, 1943a). The highest mortality rates occur within the first 2 years; the age structure of populations in Alabama suggests that mortality is higher for subadults than for juveniles (Johnson, 1970). In Missouri, the mortality rate is 56 percent (Sanderson, 1951), while in agricultural areas of Iowa it is only 38 percent (Clark et al., 1989). Clark et al. (1989) also found mortality rates of juveniles to be higher at 42 percent. Overall, raccoons in Alabama live longer than those in Missouri with longevity rates of 3.1 and 1.8 years respectively (Johnson, 1970; Sanderson, 1951).

Reproduction/Breeding

Although solitary, adult raccoons come together for a short time during the mating period (Kaufmann, 1982), which begins earlier (January to March) in their northern range than in their southern range (March to June) (Johnson, 1970; Sanderson, 1987). Male and female home ranges overlap freely and each male may mate with several females during the breeding season (Mech et al., 1966; Johnson, 1970; Kaufmann, 1982; Stuewer, 1943a). Gestation lasts 63 days (Hamilton, 1936b; Sanderson, 1987; Stuewer, 1943b) and young are weaned at 84 days (Montgomery, 1969).

Behavior and Social Organization

The most common group of raccoons is a mother and her young of that year. Further north in their range, a family will den together for the winter and break up the following spring (Kaufmann, 1982). Males are territorial toward one another but not toward females; females are not territorial (Fritzell, 1978).

3.2.13 Mule Deer (*Odocoileus hemionus*)[2]

Mule deer are in the order Artiodactyta, family Cervidae. Mule deer are also referred to as black-tailed deer, but this designation usually applies to the Pacific Coast subspecies. There are about seven generally recognized subspecies (Mackie et al., 1982). Mule deer are medium-sized cervids and are strictly herbivorous.

Distribution

Mule deer/black-tailed deer are found over most of North America from the 100th meridian to the Pacific coast and from southern Alaska to central Mexico (Mackie et al., 1982; Anderson and Wallmo, 1984).

Body Size and Weight

Mule deer are medium-sized members of the cervid family but may vary in both size and weight depending on the geographic location of a particular population. Generally, adult males weigh between 70-150 kg (Anderson and Wallmo, 1984). The largest individuals occur in the Rocky Mountains, with males averaging 152.3 cm in length and females 142.4 cm. The average weight of males and females are 74.04 kg to 58.99 kg, respectively (Mackie et al., 1982). West-coast black-tailed deer are smaller, with adult weights for males and females as low as 50 and 32 kg, respectively (Mackie et al., 1982).

Food Habits and Diet Composition

It is difficult to generalize the typical forage of mule deer; foods eaten vary dramatically in kind, quantity, and nutritional quality as well as in digestibility from one season to another, from one year to the next, and from place to place (Mackie et al., 1982). Mule deer may use many different plants at different times, some may be eaten only in certain seasons, and some parts of plants may be selected over others. In general, diets of mule deer consist mostly of browse, whereas the diets of elk, cattle, and wild horses consist mainly of sedges and grasses (Hansen and Clark, 1977). Both rumen and fecal analysis have been used to describe deer diets, and both methods give similar results (Anthony and Smith, 1974). Examples of food preferences of mule deer are presented in Table 3-28.

Food Consumption Rate

Alldredge et al. (1974) determined food intake by mule deer in Colorado. Concentrations of ^{137}Cs in deer tissue and diets were used to develop an intake and a retention function. Average intake rates varied by season, age class, and sex (Table 3-29); mean intake rate was 21.9 g of air-dried forage/kg body weight/d. More specific information on mule deer forage intake rates can be found in Collins and Urness (1983) and Wickstrom et al. (1984).

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2 Text directly from Sample et al. (1997a).

TABLE 3-28
Diet Composition of Mule Deer *(Odocoileus henionus)*

			Percentage of Diet							
Location	**Habitat**	**Season**	**Trees**	**Shrubs**	**Forbs**	**Grasses**	**Cactus**	**Fern**	**Other**	**Reference**
New Mexico	SW pinyon-juniper		75		16	2.2			6.8	Boeker et al., 1972
Arizona	Sonoran desert	Spring	4.7	37.6	22.8	2.6	29.6		2.7	Short, 1977
Arizona	Sonoran desert	Summer	24.1	38	22.4	0.4	14.1		1	Short, 1977
Arizona	Sonoran desert	Fall	3.4	48	2.5	Tr.	44.5		1.6	Short, 1977
Arizona	Sonoran desert	Winter	4.9	31.7	4.3	1	55.9		2.2	Short, 1977
Colorado	Pinyon-juniper range	Winter	81.4		10.7	7.9				Bartmann et al., 1982
Colorado	Pinyon-juniper range	Winter	90.3		8.6	1.1				Bartmann et al., 1982
Colorado	Pinyon-juniper range	Winter		93.8	5.6				1.6	Bartmann et al., 1982
Colorado	Pinyon-juniper range	Winter		89.9	6.2				3.9	Bartmann et al., 1982
Colorado	Sagebrush-steppe range	Winter		62.9	31.2	5.7			0.2	Bartmann et al., 1982
Colorado	Sagebrush-steppe range	Winter		80.7	7.2	12.1				Bartmann et al., 1982
Colorado	Old-growth forest	Fall	52	3	39	3		1	2	Leslie et al., 1984
Washington	Old-growth forest	Winter	49	4	41	2		1	3	Leslie et al., 1984
Washington	Old-growth forest	Spring	61	5	8	4		19	3	Leslie et al., 1984
Washington	Old-growth forest	Summer	60	8	8	4		13	7	Leslie et al., 1984
Washington	Old-growth forest	Fall	3	26	29	7		30	5	Leslie et al., 1984
Washington	Old-growth forest	Winter	2	43	21	6		23	5	Leslie et al., 1984
Washington	Old-growth forest	Spring	25	8	50	6		3	8	Leslie et al., 1984
Utah	Clear-cut forest	Summer	5		92				3	Deschamp et al., 1979
Utah	Dry meadow	Summer	6		83	2			9	Deschamp et al., 1979
Utah	Wet meadow	Summer	4		93				3	Deschamp et al., 1979
Utah	Mature forest	Summer	20		62		18			Deschamp et al., 1979
Utah	Stagnated forest	Summer	20		65		15			Deschamp et al., 1979

TABLE 3-29
Forage Intake Rates (g dry forage/kg/d) for Mule Deer (Alldredge et al., 1974)

	Mean (±SE)
Summer	25.7 ±2.4
Winter	20.1 ±1.2
Male	22.4 ±1.8
Female	21.5 ±1.4
Subadults	31.8 ±2.3
Adults	18.2 ±0.9
Mean for all groups	21.9 ±1.1

Wallmo et al. (1977) used several factors including body weight, metabolic weight, activity metabolic rate, forage intake, gross energy, and dry matter digestibility to develop a model to evaluate the ability of ingested forage to supply the energy needs of mule deer. This model can be used to estimate the carrying capacity of seasonal ranges for mule deer populations (Wallmo et al., 1977).

Water Consumption Rate

Mule deer obtain much of their water through succulent forage or as dew on forage plants. This is sufficient to meet their metabolic needs during the spring, summer, and fall; in the winter snow is ingested (Mackie et al., 1982). Observations of mean water intake by penned mule deer range from 24-35 mL/kg/d in winter and 47-70 mL/kg/d in the summer (Anderson and Wallmo, 1984). Water consumption by black-tailed deer ranges from 53 mL/kg/d in winter to 104 mL/kg/d in summer (Anderson and Wallmo, 1984).

Soil Ingestion

Soil ingestion rates were calculated for mule deer in north central Colorado feeding in a grassland-shrub community (Arthur and Alldredge, 1979). The intake varied by season, with a year-round average of 16.1 g/individual/d (Table 3-30). The soil ingested ranged from 0.6 to 2.1 percent of the deers' diets (dry matter intake). Beyer et al. (1994) report soil ingestion by mule deer to be <2 percent of their diet.

Respiration Rate

No literature data were found describing inhalation by mule deer. Using Eq. 21 and assuming a body weight of 57.1 kg, the average inhalation rate is estimated to be 0.24 m^3/kg BW/d. If other body weight values are used, the inhalation rate should be recalculated.

Metabolism

The mean core body temperatures of captive mule deer and black-tailed deer have been calculated. The mean (range) for a yearling male *O.h. hemionus* is 37.1°C (36.3 to 42.1; Thorne, 1975). For two male black-tail fawns the temperature was 38.9°C (38.4 to 39.8), and for two adult females the mean temperature was 38.3°C (37.8 to 39.3) (Cowan and Wood,

TABLE 3-30
Soil Ingestion Rates (g/d) by Mule Deer (Arthur and Alldredge, 1979)

	Mean (±SE)
Spring	29.6±20.1
Summer	7.7±10.2
Fall	8.8±6.5
Winter	18.3±10.8

1955b). Mule deer have a preferred ambient temperature range from about -9° to 7°C, but they can tolerate climates with average temperatures between -15° and 30°C, with extremes from -60° to 50°C (Mackie et al., 1982).

Mule deer are homiothermal and lack sweat glands. Thermoregulation from evaporation is difficult; therefore, alternative strategies are used to regulate body temperature (Mackie et al., 1982). Heat production, thermoregulation, and environmental stressors in mule deer are discussed by Nordan et al. (1970), Parker and Robbins (1984), and Parker (1988). Mautz and Fair (1980) observed a linear relationship between heart rate and energy expenditure

$$\text{kcal/kg}^{0.75}\text{/min} = 0.00143(\text{heart rate}) - 0.0186. \tag{52}$$

Although using heart rates as a predictor of energy expenditure for mule deer of similar sizes seems feasible, fluctuations by time of day and ambient temperature may limit the precision of these estimates (Freddy, 1984). The average maintenance energy requirement of fawns in winter was 158 kcal ME/kg$^{0.75}$/d, where ME = metabolizable energy (Baker et al., 1979). This is the caloric intake needed to maintain body weight equilibrium and includes the unquantified inherent cost of activity and thermoregulation (Baker et al., 1979). Kautz et al. (1982) estimated this value to be between 134 and 204 kcal/kg$^{0.75}$/d for mule deer fawns. Several studies have been done on the energy costs for different mule deer activities (Kautz et al., 1982; Parker et al., 1984). The costs of bedding, standing, walking, and trotting in kcal/kg$^{0.75}$/d are 112, 164, 326, and 1293, respectively (Kautz et al., 1982).

Habitat Requirements

Mule deer are found in all major climatic and vegetational zones of western North America. Generally, mule deer frequent semiarid, open forest, brush, and shrub lands associated with steep, broken, or otherwise rough terrain (Mackie et al., 1982). They are the most populous in mountain foothill habitats but can be found in prairie and semiarid desert habitats as well.

Home Range

Mule deer usually confine themselves to small individual home ranges, with extreme movements occurring only during migration (Mackie et al., 1982). More extreme movements may also occur as a result of severe environmental conditions. The mean annual home range size is 58.8 ha for black-tailed deer and 285.3 ha for mule deer (Anderson and Wallmo, 1984). Dasmann and Taber (1956) determined the average home range to be between 640 and 1280 m in diameter for adult does and between 822 and 1280 m for adult bucks. Robinette (1966) observed similar home range sizes in Utah.

Population Density

Population densities vary by habitat type from 0.005 to 0.02 individuals/ha in open prairies and plains, to 0.015-0.045 individuals/ha in broken prairies, and to 0.04-0.07 individuals/ha in mountain regions (Mackie et al., 1982). Winter densities of deer can get much higher with values from 0.3 to 0.5 individuals/ha (Mackie et al., 1982; Anderson and Wallmo, 1984; Dasmann and Taber, 1956). Populations may also fluctuate from year to year, increasing or decreasing the overall densities.

Population Dynamics/Survival

The abundance of mule deer is determined both by the number of deer that can be supported by a unit of area and the amount of habitat available (Mackie et al., 1982). Local populations may be influenced by many different extrinsic factors, the most important of which are habitat and nutritional limitations. Other limiting factors include weather, diseases, parasites, predation, competition, other wild and domestic ungulates, and hunting (Mackie et al., 1982). Some papers on specific mortality rates of mule deer in Colorado, Utah and Washington are White and Bartmann (1983), Robinette et al. (1957), and Taber and Dasmann (1954).

Mortality of fetuses in mule deer has been estimated at between 3.5 and 10.5 percent, with postnatal mortality of 22-53 percent for males and 17-25 percent for females (Anderson and Wallmo, 1984). Average longevity has not been determined, but some wild deer have been observed living to age 20 (Robinette et al., 1957).

Reproduction/Breeding

Mule deer are polygamous, with males wandering and seeking does in estrus. Males are highly aggressive during rut and are antagonistic toward others (Mackie et al., 1982). Females generally do not breed until their second year, with peak breeding occurring between November and December. Gestation usually lasts from 200 to 208 days with the peak births occurring in late June (Anderson and Wallmo, 1984). Does usually have one or two fetuses with triplets occurring only about 1.4 percent of the time. Weaning generally occurs from about week 5 to week 16. The length of the estrous cycle in mule deer was calculated to be between 23 and 29 days (Anderson and Wallmo, 1984). Additional information on the fertility of mule deer can be found in Robinette et al. (1955).

Behavior and Social Organization

The degree of sociability in mule deer varies according to season, sex, population, and subspecies, with most being neither highly gregarious, nor strictly solitary (Mackie et al., 1982). Mule deer are most dispersed during the summer and most congregated during the winter, as suitable habitat decreases. There have been scattered reports of group territoriality (Mackie et al., 1982). Additional information on mule deer behavior can be found in Mackie et al. (1982), Kucera (1978), and Dasmann and Taber (1956).

3.3.14 Pocket Gopher spp [3]

Pocket gophers are in the order Rodentia and family Geomyidae. There is great variability among pocket gophers, with about 30 species and more than 300 named subspecies. There are three genera of pocket gopher found in North America. These genera include the western pocket gopher (*Thomomys*), the eastern pocket gopher (*Geomys*), and the yellow-faced pocket gopher (*Pappogeomys*). Five additional genera are recognized in Central America (Hall and Kelson, 1959).

Distribution

Pocket Gophers are found from central Alberta south to Panama and occur only in the Western Hemisphere. The western pocket gopher (*Thomomys* sp.) occurs over most of western North America (Turner et al., 1973). The yellow-faced pocket gopher (*Papogeomys castanops*) is found only in the southwestern United States and into Mexico. The eastern pocket gopher (*Geomys* sp.) is found in the eastern Gulf states. No pocket gophers are found in the northeastern United States (Chase et al., 1982). Pocket gopher species are almost always allopatric in their distribution (Vaughan and Hansen, 1964). The similarity in ecological requirements of the different species probably prevents sympatric distribution (Miller, 1964; Vaughan, 1967).

Body Size and Weight

Pocket gophers have small, flat heads conducive to burrowing. Mature males range from 217 to 372 mm in total length. Males are heavier than females having 10 to 50 percent greater mass depending on species. The mean average weight of *T. Talpoides* from Utah was 91.4 g for adult females and 104.4 g for males. Body weights of pocket gophers are listed in Table 3-31.

TABLE 3-31
Body Weights (g) for the Pocket Gopher (Geomyidae spp.)

Location	Sex	N	Mean	Reference
New Mexico	Male (*G. bursirius*)	a	224.6	Best, 1973
	Male (*P. castanopus*)	a	350.5	
	Male (*T. bottae*)	a	162	
	Female (*G. bursirius*)	a	179.5	
	Female (*P. castanopus*)	a	260.8	
	Female (*T. bottae*)	a	135.7	
Colorado	Male	5	263.2	Miller, 1964
	Male	61	258.8	
	Male	71	235.2	
	Male	126	206.8	
	Female	10	255	
	Female	92	237.7	
	Female	66	220	
	Female	179	203	

a - Not stated

[3] New species accounts compiled for ARAMS.

Food Habits and Diet Composition

Herbivorous in nature, gophers utilize a wide variety of plants in their diet. They are opportunistic and collect food above ground outside of their feeding holes. Occasionally they eat roots and when necessary they eat above ground woody vegetation (Chase et al., 1982; Miller, 1964). The diet composition of pocket gophers is detailed in Table 3-32.

TABLE 3-32
Diet Composition of the Pocket Gopher (Geomyidae spp.)

Location	Prey Taxon	Percent Volume	Reference
Oregon	Aboveground plant parts:		Chase et al., 1982
	Forbs	40	
	Grasses	32	
	Roots	24	
	Woody plants	4	
Colorado	Forbs	67	Chase et al., 1982
	Grasses	30	
Utah (material found in caches)	Claytonia lanceolata & Orogenia linearifolia	82.5	Stuebe and Anderson, 1985
	Delphinium nelsoni	6.7	
	Stellaria jamesiana	6.2	
	Ranunculus jovis	3	
	Erythronium grandiflorum	1.2	
	Hydrophyllum capitatum	0.4	

Food Consumption Rate

Feeding rate of *T. bottae* was calculated in a study by Gettinger (1984). The feeding rate for free-ranging gophers in the summer was 126.5 $\pm$ 12.1 g/kg BW/day (0.13 $\pm$ 0.01 kg/kg BW/day) and was determined from the following relationship: [(field energy metabolism/assimilation efficiency)/energy content of food]. When determined using $^{3}HH^{18}O$ turnover rates and H_2O content of the diet, assuming gophers didn't drink, the rate was 121.7 $\pm$ 8.6 g/kg/day (0.12 $\pm$ 0.01 kg/kg BW/day). The winter rate was 111.4 $\pm$ 5.3 g/kg/day (0.11 $\pm$ 0.01 kg/kg BW/day) based on the previous equation and 100.1 $\pm$ 8.6 (0.10 $\pm$ 0.01 kg/kg BW/day) based on the $^{3}HH^{18}O$ turnover rates. Using Eq. 6 and assuming a mean body weight of 0.23 kg (as calculated using above body weight table and adults) a food consumption rate of 0.058 kg/kg BW/day can be calculated. A fresh weight of 0.34 kg/kg BW/day can be calculated assuming a diet of 67 percent forbs and 30 percent grasses (Vaughan, 1967) with respective water contents of 85 and 79 percent (Table 3-4). (Note: If using other body weight values, then the rate should be recalculated).

Water Consumption Rate

Most of the water requirements for the pocket gopher are provided by their diet (Bailey, 1895; Tietjen et al., 1967). Using Eq. 19 and assuming a mean body weight of 0.23 kg, a water consumption rate of 0.12 L/kg BW/day can be estimated. (Note: If using other body weight values, then the rate should be recalculated).

Soil Ingestion

Data concerning soil ingestion by pocket gophers was not located in the literature. Beyer et al. (1994) reported soil ingestion by burrowing rodents (woodchucks and prairie dogs) to range from <2 to 7.7 percent of their diet. As a burrowing rodent, soil ingestion by pocket gophers is likely to be comparable to these values.

Respiration Rate

No information was found in the literature about respiration rate. An estimate of 0.73 m^3/kg BW/day can be calculated using Eq. 21 and a mean body weight of 0.23 kg. (Note: If using other body weight values, then the rate should be recalculated).

Metabolism

Gettinger (1984) determined metabolic rates and field energy metabolism in a study analyzing energy and water metabolism of the pocket gopher. Metabolic rates varied between seasons and were estimated for summer, winter and spring. The rate calculated during the summer was 2.41 $\pm$ 0.22 mL/g BW/h (1273.7 $\pm$ 119.5 kJ/kg BW/day). For winter, rates were 2.24 $\pm$ 0.11 mL/g BW/h or 1180.4 $\pm$ 56.5 kJ/kg BW/day. Metabolic rates in the spring were 2.34 $\pm$ 0.1 mL/g BW/h (1308.1 $\pm$ 51 kJ/kg BW/day).

Habitat Requirements

Pocket gophers occur in a wide range of environments from high mountain meadows to lowland plains and rangelands. The main factor that limits distribution is soil type. Optimum soils are light, porous, and have good drainage. Soil depth also impacts distribution as shallow soils can cause cave-ins and limit protection from ground temperatures. Consequently, a combination of soil depth and local climate influences the local distribution of pocket gophers (Kennerly, 1964; McNabb, 1966; Turner et al., 1973).

Home Range

The home range for *T. bottae* was found to average 250 m^2 (0.025 ha) with a maximum of 445 m^2 (0.045 ha). Females had home ranges that were half as large as males with an average of 120 m^2 (0.012 ha) and a maximum of 240 m^2 (0.024 ha). Home range was found to be synonymous with territory, changing when territorial boundaries changed (Howard and Childs, 1959). Tietjen et al. (1967), Hansen and Reid (1973), and Turner et al. (1973) reported comparable data for *T. talpodes*.

During the breeding season home ranges of males did not overlap with other males, but did overlapped with one to four females. Female home ranges did not overlap significantly (Howard and Childs, 1959).

Population Density

The density of gophers is variable based on local climate, suitability of the soil, kind and amount of soil drainage, altitude, land use, and other habitat factors. *T. talpoides* in the subalpine zone of Colorado were much more plentiful than in the low shrub-grassland zone. Densities in grazed rangelands of ponderosa pines and bunchgrass were 9.9 gophers per ha but in similar ungrazed habitats densities were as high as 22.2 gophers/ha (Turner et al., 1973). On the San Joaquin Experimental range in California densities ranged from 8 to

17 gophers/ha (Chase et al., 1982). In San Diego, California valley pocket gophers have been estimated to occur in densities of 40 gophers/ha (Cox and Hunt, 1992). Populations are usually highest during the fall.

Population Dynamics/Survival

In general, the rate of predation has little effect on pocket gopher population sizes. Instead, the suitability of the habitat (e.g., food, cover, soil type, and moisture), as well as competition between pocket gophers and other intrinsic factors are more important to population regulation (Howard and Childs, 1959). Snowmelts, in particular can have a dramatic impact on pocket gopher populations because resulting high water tables can cause significant mortality in young and adult gophers (Chase et al., 1982). Important predators include coyotes, foxes, bobcats, badgers, skunks, weasels, house cats, many species of hawk and owl, gopher snakes, and rattlesnakes (Chase et al., 1982). The maximum longevity for pocket gophers is 5 years with the oldest gopher being found in Colorado (Reid, 1973). In a field study, mean lifespan for gophers was about 13.6 months for males and 18.3 months for females (Howard and Childs, 1959).

Reproduction/Breeding

Pocket gopher nests are located in burrows and sometimes, depending on species, are made of dried plant parts. Soils are friable and often relatively moist. Pocket gophers begin breeding at one year of age, generally producing one litter a year (Hansen, 1960). However, Miller (1946) found that one species of pocket gopher (*T. bottae*) had multiple litters. Number of young per litter ranges from 3.2 to 6.4 (Hansen, 1960). The gestation period was estimated at 18 or 19 days in western pocket gophers bred in captivity (Schramm, 1961; Turner et al., 1973; Andersen, 1978). Young are weaned when they are 35 to 40 days old (Howard and Childs, 1959). Young pocket gophers disperse above-ground with approximately 62 percent of the disperses being male (Chase et al., 1982).

Behavior and Social Organization

Pocket gophers are active all year with peaks in activity during the fall when populations are highest. Very little surface activity has been noted to occur from June to September. It is suggested that at this time gophers retreat to deeper borrow systems and go into short estivation (Howard and Childs, 1959). Feeding and burrowing occurs during the day underground. Gophers are very docile and can reportedly be picked up by the tail without biting. Gophers are, however, territorial and intolerant of one another except during breeding season. It is not uncommon for multiple combinations of male and female gophers to share burrows during breeding season. Territorial boundaries are relaxed during breeding season and reestablished in September (Miller and Bond, 1960).

3.2.15 Great Basin Pocket Mouse (*Perognathus parvus*)[2]

Pocket mice are in the order Rodentia, family Heteromyidae. Pocket mice are the smallest members of this family that includes kangaroo mice and kangaroo rats. A key characteristic of the family is fur-lined cheek pouches (Burt and Grossenheider, 1976). Members of this family are all adapted to arid conditions, many, including pocket mice, do not require

[2] Text directly from Sample et al. (1997a).

drinking water (Vaughan, 1978; Burt and Grossenheider, 1976). *P. parvus* is a semifossorial granivorous species of arid or semiarid habitats (Verts and Kirkland, 1988).

Distribution

Pocket mice (*Perognathus spp.*) are found only in western North America, west of the Mississippi river. *P. parvus* occurs throughout the Great Basin region, from southern British Columbia to northern Arizona (Burt and Grossenheider, 1976; Verts and Kirkland, 1988).

Body Size and Weight

Pocket mice are approximately the size of the house mouse (*Mus musculus*) with longer tails and smaller ears (Scheffer, 1938). Males are slightly larger than females; total lengths of males and females from Utah were 174 and 172 mm, respectively (Verts and Kirkland, 1988). Tail length is 110 to 120 percent of body length. Body weights for male and female pocket mice from several locations are presented in Table 3-33. O'Farrell (1975a) observed that body weights of males increase with increasing elevation.

TABLE 3-33
Body Weights (g) for the Great Basin Pocket Mouse, *Perognathus parvus*

Location	Sex	N	Mean	Minimum	Maximum	Reference
Washington	Male	10	17.25			Scheffer, 1938
	Female	10	14.3			
Nevada	Male	10	25.4	21.5	31.0	Verts and Kirkland, 1988
	Female	10	20.5	16.5	28.5	
Washington	Male: 500 ft	18	17.4±0.3[a]			O'Farrell et al., 1975
	Male: 1500 ft	12	18.3±0.3[a]			
	Male: 2500 ft	11	17.6±0.4[a]			
	Male: 3500 ft	12	19.1±0.5[a]			
Washington	Male	12	17.66±1.32[b]	15.52	19.62	Schreiber, 1978
	Female	12	15.82±1.34[b]	13.16	17.47	

[a] mean±standard error
[b] mean±standard deviation

Food Habits and Diet Composition

Although the diet of *Perognathus parvus* consists primarily of seeds (Scheffer, 1938; Martin et al., 1951; Kritzman, 1974), insects may be consumed in spring, before seeds become available (Kritzman, 1974; O'Farrell et al., 1975). When grass seeds were ripe, they represented 88 percent of the seeds in cheek pouches of mice in eastern Washington (Kritzman, 1974). Food preferences of pocket mice from several locations are listed in Table 3-34.

Food Consumption Rate

Schreiber (1978) estimates the daily energy requirements for male and female *P. parvus* in Washington in winter to be 2.36 and 2.63 kcal, respectively. In contrast, energy requirements in spring are 6.96 and 6.55 kcal for adult males and females, respectively. Based on estimated daily maintenance energy requirements and caloric content of cheatgrass seeds, Schreiber (1978) estimated the daily food consumption rate. Mean (±STD) ingestion for

8 individuals (4 male, 4 female) was 0.076±0.023 g/g/d. Females consumed somewhat more food/g than males (females: 0.079±0.026 g/g/d; males: 0.073±0.020 g/g/d).

TABLE 3-34
Diet Composition of Pocket Mice (*Perognathus parvus)*

Location	Foods Consumed (%)	Comments	Reference
California	Poison ivy (10-25) Filaree (10-25) Deervetch (10-25) Ryegrass (2-5) Oats (2-5) Nightshade (2-5) Bitterbrush (2-5) Saltbrush, knotweed (1/2-2)	Data are for pocket mice in general. Scientific names not reported. Values in parentheses refer to percentage use as reported by the authors. Data from spring, fall, and winter only.	Martin et al., 1951
Western Prairies and Mt-Deserts	Mesquite (10-25) Locoweed (5-10) Creosote (5-10) Beeplant (5-10) Pigweed (5-10) Cedar (5-10) Fescuegrass (2-5) Saltbush (2-5) Pricklypear (2-5) Bromegrass (2-5) Morning-glory (2-5) Bristlegrass (2-5) Sunflower (2-5) Plantain (2-5) Deervetch (2-5) Barley (2-5) Russianthistle (2-5) Nightshade, knotweed, sagebrush (1/2-2)	Data are for pocket mice in general. Values in parentheses refer to percentage use as reported by the authors. Data from throughout year.	Martin et al., 1951
Eastern Washington	*Amsinckia* seeds (2.5) *Cryptantha* seeds (0.5) *Salsola* seeds (6.3) *Aster* seeds (0.4) *Franseria* seeds (0.1) *Descurania* pods (3.3) *Agropyron* seeds (5.5) *Bromus* seeds (45.6) *Festuca* seeds (20.0) *Gilia* seeds (0.8) *Microsteris* (11.5) Root nodules (0.3) Stem and leaf pieces (2.9) Insect larvae (0.2)	Contents of cheek pouches from 52 *P. parvus* collected May-October 1969. Data presented as frequency of occurrence over all samples.	Kritzman, 1974

Water Consumption Rate

Pocket mice generally do not require water other than that contained in their food (Scheffer, 1938, Kritzman, 1974, Vert and Kirkland, 1988). Schmidt-Nielson et al. (1948) studied water conservation in desert rodents, including *Perognathus baileyi*. Mice survived well and gained weight when maintained for up to six weeks on a dry diet with no drinking water. In contrast, white rats and woodrats (N*eotoma*) maintained under similar conditions lost weight and had all died by 21 and 9 days, respectively (Schmidt-Nielson et al., 1948). Water balance is maintained by excreting concentrated urine, obtaining water from food and water generated through metabolism (Vert and Kirkland, 1988); consequently drinking water is not required.

Soil Ingestion Rate

Data concerning soil ingestion by *P. parvus* was not located in the literature. Beyer et al. (1994) report soil ingestion by burrowing rodents (woodchucks and prairie dogs) to range from <2 to 7.7 percent of their diet. As a burrowing rodent, soil ingestion by *P. parvus* is likely to be comparable to these values.

Respiration Rate

No literature data were found describing inhalation by *P. parvus*. Using Eq. 21 and assuming a body weight of 18 g for males and 16 g for females (Table 3-33), the average inhalation rate is estimated to be 1.22 m^3/kg BW/d for males and 1.25 m^3/kg BW/d for females. If other body weight values are used, the inhalation rate should be recalculated.

Metabolism

The bioenergetics of *P. parvus* was studied by Schreiber (1978). Annual energy intakes for males and females was estimated to be 2550 kcal/y and 2462 kcal/y, respectively. Summer torpor reduces energy demand by 3 percent. In winter, the reduction was 40-43 percent lower than summer, because of more extensive torpor. Metabolic rates for active, resting, nesting, and torpid *P. parvus* are related to ambient temperature and may be estimated as follows:

$$M_{active} = 11.5-0.24T_a,$$

$$M_{resting} = 8.6-0.24T_a,$$

$$M_{nest} = 7.0-0.165T_a,$$

and

$$M_{torpor} = 0.38+0.014T_a,$$

where

M_{active} = metabolic rate for active individuals (mL O_2/g/h),

M_{resing} = metabolic rate for resting individuals (mL O_2/g/h),

M_{nest} = metabolic rate for individuals in nests (mL O_2/g/h),

M_{torpor} = metabolic rate for torpid individuals (mL O_2/g/h),

T_a = ambient temperature (°C).

Schreiber (1978) also presents models for estimating annual energy expenditure.

Habitat Requirements

P. parvus prefers arid to semiarid environments that are predominantly sandy and dominated by sagebrush (Verts and Kirkland, 1988). O'Farrell (1975b) describes the habitat requirements in Washington to be shrub-steppe with light-textured soils. Abundance of *P. parvus* is greater at sites with abundant seed-producing annuals and lower in perennial grasslands or locations where springtime soil temperatures <40°F are extensive (O'Farrell, 1975a). While *P. parvus* were captured at all elevations on the Hanford Reservation from 500-3500 ft., 37 percent of all individuals were collected at lower elevations (e.g., 500 ft.; O'Farrell, 1975a).

Home Range

The home range of male *P. parvus* in Washington ranged from 0.156 to 0.4 ha, while those for females ranged from 0.05 to 0.23 ha (O'Farrell et al., 1975). Home range size is inversely related to population density. In southern British Columbia, home ranges range from 0.066 to 0.09 ha (Schreiber, 1978). In related species, Blair (1953) reports home ranges of male and female *P. merriami* to be 1.88 and 5.87 acres (0.76 and 2.4 ha), respectively. Average home ranges of male *P. penicillatus* in New Mexico were 2.72±0.48 acres (1.1±0.2 ha), with a maximum of 5.54 acres (2.24 ha). In contrast, average home range of females was 1.09±0.14 acres (0.44±0.06 ha), with a maximum of 1.43 acres (0.58 ha; Blair, 1953).

Population Den

Average peak autumn population density in Washington was 118.5 individuals/ha, but ranged from a high of 162 to a low of 76.3 (O'Farrell et al., 1975). Annual average population densities of 28.5/ha (peak of 42/ha) and 82.3/ha have been reported for southeast Washington and the Yakima Valley, respectively (Verts and Kirkland, 1988). Schreiber (1978) suggests that at high densities, *P. parvus* may become food stressed. He estimates the maximum sustainable density to be 39-83 individuals/ha.

Population Dynamics/Survival

One, two, and three-year survival rates of *P. parvus* in Washington are reported to be 56-80 percent, 17-19 percent, and 2-3 percent, respectively (O'Farrell et al., 1975). The highest winter survival was observed among juveniles born when precipitation, food supply, and reproduction was lowest. Summer population size was highly correlated to October-April precipitation (O'Farrell et al., 1975). This rainfall stimulates growth and reproduction in vegetation and consequently affects small mammal numbers.

Reproduction and Breeding

Under favorable conditions, *P. parvus* generally have two litters per female per year; only one during poor years (Kritzman, 1974). Duration of the breeding season varies from four months (April-July) to six months (March-August depending on elevation (i.e., shorter at higher elevations; O'Farrell, 1975). Scheffer (1938) suggests that the gestation period is 21 to 28 days. Litter sizes average approximately five (Scheffer, 1938; Duke, 1957) and may range from two to eight (Scheffer, 1938, Speth et al., 1968). Males become sexually active in spring (before May) and remain active through August (Speth et al., 1968). O'Farrell et al. (1975) observed the first signs of estrus in females in April, first pregnancies in May, and last pregnancies in August.

Behavior

P. parvus is semifossorial, spending a considerable amount of time underground. Burrows, approximately 25 mm in diameter, ending in a ball-shaped chamber, are constructed 13-30 cm below the soil surface (Scheffer, 1938). Burrows may extend as deep as 1 m (Verts and Kirkland, 1988). While *P. parvus* is generally nocturnal or crepuscular, individuals may be active during the day (Scheffer, 1938). Activity is suppressed by inclement weather.

Social Organization

P. parvus is not considered social, individuals occupy separate nests in the wild (Scheffer, 1938, Verts and Kirkland, 1988). Conspecifics housed together will fight initially but later tolerate each other (Scheffer, 1938). In contrast, *P. parvus* attacks other rodent species it may be housed with (Verts and Kirkland, 1988).

3.2.16 Pine Vole (*Microtus pinetorum*)[2]

Pine voles are in the order Rodentia, family Cricetidae. Related species include the meadow vole (*M. pennsylvanicus*) and prairie vole (*M. ochrogaster*). The pine vole is a semifossorial herbivore of wooded habitats (Burt and Grossenheider, 1976).

Distribution

The pine vole occurs throughout much of the eastern United States. Its range extends from the Atlantic coast to eastern Texas, north to Wisconsin, southern Ontario, and southern New England (Burt and Grossenheider, 1976; Smolen, 1981; Johnson and Johnson, 1982).

Body Size and Weight

The body form of the meadow vole is cylindrical and slender with reduced eyes, ears, and tail, consistent with a semifossorial lifestyle (Smolen, 1981). The body length of adults averages approximately 120 mm (Smolen, 1981). Female pine voles are generally slightly larger than males (Table 14; Smolen, 1981). Body weights of pine voles from several locations are listed in Table 3-35.

Food Habits and Diet Composition

Pine voles are primarily herbivores; however, snails (Martin et al., 1951) or beetles (Benton, 1955) may be consumed. Hamilton (1938) reports that pine voles feed largely on succulent roots and tubers. In New York and New Jersey, the diet of pine voles consists of bulbs, tubers, roots, seeds, fruit, bark, and leaves (Benton, 1955). Diet varies by season: grass roots and stems are eaten in summer, fruit and seeds in fall, and bark, roots, and stored foods in winter (Benton, 1955). Pine voles may be a serious pest in orchards, eating the bark and roots of fruit trees (Johnson and Johnson, 1982, Swihart, 1990). Lists of species of plants consumed are presented in Smolen (1981) and Martin et al. (1951). A summary of food habitats of pine voles in North Carolina and Virginia is presented in Table 3-36.

[2] Text directly from Sample et al. (1997a).

TABLE 3-35
Body Weights (g) for the Pine Vole (*Microtus pinetorum)*

Location	Sex	N	Mean	Range	Reference
Virginia	Male	11	25.4±1.5	23.4-28.2	Cengel et al., 1978[a]
	Female: nonpregnant	11	24.8±1.8	21.6-27.9	
New York and New Jersey	Adults: sex not differentiated	25	25.6	22-37	Benton, 1955
Vermont	Adults: sex not differentiated	4	26.1	20.6-30.3	Miller, 1964
Connecticut	Adults	18	23.9	20.5-29.0	Miller and Getz, 1969
	Sub-adults	10	19.0	16.0-21.0	
	Juveniles	4	13.5	12.0-14.5	
Louisiana	Adults	2	25.6	25.2-26.0	Lowery, 1974
Indiana	Female		27.2	22.7-33.8	Silva and Downing 1995
	Male		25.5	23.3-29.5	
Georgia	Male	17	24.2	14.5-28.6	Smolen, 1981
	Female	6	27.4	23.1-30.8	

[a]Values represent mean and range of means from 11 separate observations.

TABLE 3-36
Diet Composition of Pine Voles (*Microtus pinetorum)*

Location	Date	Food type	Percent Volume	Percent Frequency	Comments	Reference
North Carolina (n=11)		Endogone (fungus)	0.4	54.5		Linzey and Linzey, 1973
		Unidentified vegetation	78.5	100		
			0.2	9.1		
		Fruit	20.6	36.4		
		Unidentified seeds	T	36.4		
		Hair	0.3	36.4		
		Pebbles				
Virginia (n=5/date and location)	July -M	Grass	20		Values extrapolated from histogram	Cengel et al., 1978
		Forb	78			
		Bulb	2			
		Grass				
	September-M	Forb	60			
		Root	36			
		Apple fruit	2			
			2			
		Grass				
	September-A	Forb	15			
		Root	81			
		Bulb	2			

TABLE 3-36
Diet Composition of Pine Voles (*Microtus pinetorum)*

Location	Date	Food type	Percent Volume	Percent Frequency	Comments	Reference
			2			
		Grass				
	November-M	Forb	80			
		Root	16			
		Bulb	2			
			2			
		Grass				
	November-A	Forb	30			
		Root	63			
		Bulb	2			
			5			
		Grass				
	January-M	Forb	82			
		Root	2			
		Apple fruit	9			
			7			
		Grass				
	January-A	Forb	4			
		Root	88			
			8			
		Grass				
	March-M	Root	85			
		Bulb	13			
			2			
		Grass				
	March-A	Forb	20			
		Root	65			
			15			
		Grass				
	May-M	Forb	12			
			88			
		Grass				
	May-A	Forb	4			
			96			

[a]M = maintained orchard
[b]A = abandoned orchard

Food Consumption Rate

In a study of the efficacy of feeding repellants on consumption of apple twigs by pine voles, mean consumption (in the absence of alternate foods) was 0.051 g/g/d (Swihart, 1990). While no other data concerning feeding rates in pine voles were found, data are available for related species. Among meadow voles, food intake when exposed to 14-h days was

0.095±0.002 (mean±SE) g/g/d; intake by individuals exposed to 10-h days was 0.085±0.005 g/g/d (Dark et al., 1983). Mean food consumption by prairie voles (assumed to weigh 35 g; Burt and Grossenheider, 1976) was 0.088 g/g/d and 0.12 g/g/d when ambient temperatures were 21° and 28°C, respectively (Dice, 1922).

Water Consumption Rate

Odum (1944) reports the daily water consumption for a single male pine vole to be 0.3 L/kg/d. In prairie voles (*M. ochrogaster*), water consumption was 0.37 and 0.43 L/kg/d for two individuals (Chew, 1951). In contrast, Dice (1922) reports mean water consumption for this same species to be 6.2±3.1 mL/individual/d. Assuming a body weight of 35 g (Burt and Grossenheider, 1976), mean water consumption was 0.18±0.08 L/kg/d. Using Eq. 19 and assuming a body weight for pine voles of 25 g, water ingestion is estimated to average 0.14 L/kg BW/d. (Note: If other body weight values are used, the water ingestion rate should be recalculated.) Benton (1955) suggests that because of the high water content of their diet, pine voles may not require drinking water.

Soil Ingestion

Data concerning soil ingestion by pine voles was not located in the literature. Beyer et al. (1994), however, reports soil ingestion by meadow voles to be 2.4 percent of diet. Soil ingestion by pine voles is likely to be comparable or higher because of the greater fossorial nature of pine voles relative to meadow voles.

Respiration Rate

No literature data were found describing inhalation by pine voles. Using Eq. 21 and assuming a body weight of 25 g (Table 3-35), the average inhalation rate is estimated to be 1.14 m^3/kg BW/d If other body weight values are used, the inhalation rate should be recalculated.

Metabolism

No literature data were found concerning metabolism in the pine vole. In a related species, the montane vole (*M. montanus*), resting metabolism declined from 3.46±0.15 mL O_2/g/h at 20°C to 2.05±0.07 mL O_2/g/h at 34°C and then increased to 2.71±0.09 mL O_2/g/h at 38°C (Tomasi, 1985). In meadow voles, resting metabolism was 2.7 mL O_2/g/h (Altman and Dittmer, 1974).

Habitat Requirements

Throughout their range, pine voles occur in a wide variety of habitats, ranging from closed-canopy beech-maple forests with extensive litter (Miller, 1964) to grassy fields with brush (Smolen, 1981). Pine voles are not restricted to pine forests, as suggested by their common name; in Louisiana, they are more frequently found in hardwood stands (Lowery, 1974). Key habitat requirements consist of well-drained soil with thick ground cover of litter or vegetation (Smolen, 1981).

Home Range

Pine voles are very sedentary, moving only short distances (Lowery, 1974). Home ranges are generally defined by the extent of their burrow system (Smolen, 1981). The home range of

17 individuals in an oak-hickory woodland averaged 34.7 m in diameter (range: 13.7-85 m; Benton, 1955). In New York, the average home range of 13 individuals was 19.2 m in diameter (Benton, 1955). In dry upland hardwood forest, average home ranges were 33.7 m (range: 10-148) and 32.7 m (10-73 m) for females and males, respectively (Miller and Getz, 1969).

Population Density

Population density in a 3-ha, dry upland site ranged from 0 to 14.6 voles/ha (Miller and Getz, 1969); density in an adjacent mixed conifer-hardwood swamp was <2 voles/ha. Densities are generally greater in orchards than in natural forests. Density estimates for an orchard in New York ranged from 80 to 120 voles/ha (Hamilton, 1938).

Population Dynamics/Survival

Pine vole populations are very local and highly variable (Benton, 1955). Miller and Getz (1969) observed mean survival in a high-density upland population to be 2.6 months; maximum observed survival was 12 and 10 months for 2 males and 2 females, respectively. Average survival from one year to the next is reported to be 58 percent for adults and 57 percent for juveniles (Smolen, 1981).

Reproduction/Breeding

Breeding occurs from January to October in the north portion of the range (Benton, 1955) but may be year-round in the south (Lowery, 1974). Miller and Getz (1969) estimate the breeding season in Connecticut to extend from mid-February through mid-November. Peak breeding occurs in March and April (Benton, 1955). Females are aggressors during mating, which is brief, lasting only a few seconds (Benton, 1955). Gestation is estimated to be 20 to 24 days. Hamilton (1938) provides a detailed description of the development of juvenile pine voles. Litter size generally ranges from two to four (Hamilton, 1938, Benton, 1955). Because female pine voles have only four mammae, large litters are unsuccessful (Smolen, 1981). Although litter size is unaffected by day length, juvenile growth is greater under a short photoperiod (8L:16D; Derting and Cranford, 1989). Female pine voles are mature in 10 to 12 weeks and are generally breeding by 15 weeks (Smolen, 1981).

Behavior

Pine voles are semifossorial, spending considerable time in subsurface burrows and surface runways (Smolen, 1981). Borrows are generally 3.8-5 cm in diameter beneath leaves and litter and are rarely 30 cm deep, generally 7.6 to 10 cm at most (Hamilton, 1938). In areas with thick litter, surface runways may be constructed (Smolen, 1981). Surface activity is not correlated with temperature or humidity (Miller and Getz, 1969). Although mostly nocturnal or crepuscular, pine voles may occasionally be active during the day (Lowery, 1974). Miller and Getz (1969) report that nocturnal and crepuscular activity was only slightly greater than daytime activity.

Social Organization

Captures of multiple individuals in the same trap suggest a degree of sociability in this species (Miller and Getz, 1969). Pine voles are not territorial; multiple individuals may share the same burrow system (Smolen, 1981).

3.2.17 Prairie Vole (*Microtus ochrogaster*)[1]

Prairie voles are in the order Rodentia family Muridae (subfamily Arvicolinae). New world voles are mall, herbivorous rodents that reside in all areas of the United States where good grass cover exists. Their presence is characterized by narrow runways through matted grasses. *Microtus* species are adapted to underground, terrestrial, and sometimes semiamphibious habitats (Johnson and Johnson, 1982). They are active by day and night and feed mainly on shoots, grasses, and bark (Johnson and Johnson, 1982). Voles are prey for snakes, raptors, and mammalian predators such as short-tailed shrews, badgers, raccoons, coyotes, and foxes (Eadie, 1952; Johnson and Johnson, 1982; Martin, 1956). The prairie vole represents the ground-burrowing members of this group.

Distribution

This vole is found in the north and central plains of the United States and in southern Canada, usually in dry places such as prairies and along fencerows and railroads. Its range has expanded eastward to West Virginia as a result of clear-cutting of forests (Jones et al., 1983). Voles are active by day or night (Johnson and Johnson, 1982). Although prairie and meadow voles usually occupy different habitats, where they coexist their population densities tend to be negatively correlated (Klatt, 1985; Krebs, 1977).

Body Size and Weight

The prairie vole measures from 8.9 to 13 cm in length and has a 3.0-to 4.1-cm tail (Burt and Grossenheider, 1980). After reaching sexual maturity, voles continue to grow for several months (Johnson and Johnson, 1982). Adults weigh from 30 to 45 g. Prairie voles maintain a relatively constant proportion of their body weight as fat (15 to 16 percent on a dry-weight basis) throughout the year (Fleharty et al., 1973).

TABLE 3-37
Body Weights (g) of the Prairie Vole (*Microtus ochrogaster*)

Location	Sex	N	Mean	Reference
ne Colorado	Adults both		41.6	Abramsky and Tracy, 1980
	(summer)		41.9	
	(fall)		44.2	
	(winter)		39.0	
	(spring)		41.3	
s Indiana	Adult Male		31.3 ± 0.35	Myers and Krebs, 1971
	Adult Female		33.3 ± 0.30	
ne Kansas	neonate (both)		2.8 ± 0.4	Martin, 1956

1 All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

Food Habits and Diet Composition

Voles, are largely herbivorous, consuming primarily green succulent vegetation but also roots, bark, seeds, fungi, arthropods, and animal matter (Johnson and Johnson, 1982; Lomolino, 1984; Stalling, 1990). Voles have masticatory and digestive systems that allow them to digest fibrous grasses such as cereals (Johnson and Johnson, 1982). Diet varies by season and habitat according to plant availability, although meadow and other voles show a preference for young, tender vegetation (Johnson and Johnson, 1982; Martin, 1956). Voles can damage pastures, grasslands, crops such as hay and grain, and fruit trees (by eating bark and roots) (Johnson and Johnson, 1982).

TABLE 3-38
Diet Consumption of the Prairie Vole (*Microtus ochrogaster*)

Location/Habitat	Dietary Composition	Spring	Summer	Fall	Winter	Reference
Kansas/ grass and forb field	*Sporibolus asper*		19.5			Fleharty and Olson, 1969
	Kochia scoparia		22.5			
	Bouteloua gracilis		6.5			(% volume stomach contents)
	Bromus japonicus		8.5			
	Rumex crispus		9.2			(Items less than 2% of volume were combined as "other")
	Triticum aestivum		3.4			
	Carex sp.		2.0			
	Other		28.3			
	(grasses)		(53.5)			
	(forbs)		(46.5)			
Missouri/old field	*Festuca arundinacea*	20.5	25.0	10.6	28.9	Cook et al, 1982
	Dactylis glomerata	6.7	1.7	1.1	4.2	
	Pheleum pratense	8.3	2.0	2.1	5.3	(mean number of food items; stomach contents)
	Tridens flavus	17.1	11.1	1.9	11.0	
	Setaria viridis	6.7	6.2	1.7	6.2	
	Taraxacum officinale	5.8	4.8	3.9	1.5	
	Lamium amplexicaule	3.9	2.9	5.2	3.4	
	Bromus tectorum	2.8	4.7	2.5	4.8	(Plants parts consumed: Leaf, stem and

TABLE 3-38
Diet Consumption of the Prairie Vole (*Microtus ochrogaster*)

Location/Habitat	Dietary Composition	Spring	Summer	Fall	Winter	Reference
						seeds of *Festuca* and *Bromus*; leaf and stem of *Tridens* and *Setaria faberi*, leaf and seeds of *Dactylis* and *Setaria viridis*; and leaves only of all other plant species)
	Setaria faberi	5.6	3.9	0.7	21.0	
	Capsella bursa-past.	2.7	1.2	0.5	0.6	
	Trifoilium stolonifera	2.4	0.8	0.5	1.4	
	arthropods	0.2	0.3	0	0.1	
	animal material	0	0.2	0.2	0	
	other	3.9	1.4	1.5	0.9	

Food Consumption Rate

Food consumption rates are variable with temperature. In laboratory studies, Dice (1922) found the ingestion rates for adults of both sexes was 0.13-0.14 g/g-day at 21 °C, but dropped to 0.09-0.10 g/g-day at 28°C.

Using Eq. 5 and assuming a mean body weight of 0.039 kg (as calculated from the above table using adults) a food consumption rate of 0.12 kg/kg BW/day was estimated. To determine the fresh weight, a diet of 53.5 percent grasses and 46.5 percent forbs (Fleharty and Olson, 1969) with respective water contents of 79 and 85 percent (Table 3-4) was used. The fresh weight estimate was 0.68 kg/kg BW/day. (Note: if body weights are different, then the rate should be recalculated)

Water Consumption Rate

Laboratory studies have reported water ingestion rates ranging from 0.21 to 0.37 g/g-day (Dupre, 1983; Chew, 1951; Dice, 1922). Estimated water consumption using Eq. 19 and body weights from Abramsky and Tracy (1981) were 0.14 L/kg BW/day. (Note: If different body weights are used, then the rate should be recalculated).

Soil Ingestion

Although no data are available on soil ingestion in prairie voles, soil ingestion was estimated for the meadow vole by Beyer et al. (1994) at a rate of 2.4 percent of the diet. Due to similar feeding habits among these two species, this rate is assumed to be representative of prairie voles.

Respiration Rate

No literature reporting respiration rates in prairie voles was available. Therefore, an inhalation rate of 1.03 m^3/kgBW/day for adults of both sexes was estimated using Eq. 21 and summer body weights from Abramsky and Tracy (1980). (Note: If different body weights are used, then the rate should be recalculated)

Metabolism

The estimated basal metabolic rates for adults of both sexes is 177 kcal/kg BW/day, using the equation in Boddington (1978) and body weights from Abramsky and Tracy (1980). The estimated free living metabolic rates for adults of both sexes is 399 kcal/kg BW/day, using the equation in Nagy (1987) and body weights from Abramsky and Tracy (1980). (Note: if different body weights are used, then the rate should be recalculated)

Unlike some other mammals, prairie voles do not hibernate or exhibit torpor (Johnson and Johnson, 1982). They overwinter without using their lipid reserves, finding food to meet their metabolic requirements year-round (Fleharty et al., 1973). Prairie voles use burrows, runways, nests, and snow cover to help maintain their body temperature. They also modify when they are active to avoid excessively hot or cold temperatures (Johnson and Johnson, 1982). Voles undergo three molts (juvenile, subadult, and adult), and molting may occur at any time during the year (Jameson, 1947, as cited in Stalling, 1990). The subadult-to-adult molt occurs between 8 and 12 weeks of age (Martin, 1956).

Habitat Requirements

The prairie vole inhabits a wide variety of prairie plant communities and moisture regimes, including riparian, short-grass, or tall-grass communities (Kaufman and Fleharty, 1974). Prairie voles prefer areas of dense vegetation, such as grass, alfalfa, or clover (Carroll and Getz, 1976); their presence in a habitat depends on suitable cover for runways (Kaufman and Fleharty, 1974). They will tolerate sparser plant cover than the meadow vole because the prairie vole usually nests in burrows at least 50 mm underground or in grass nests under logs or boards (Klatt and Getz, 1987).

Home Range

Adults of both sexes inhabiting bluegrass areas of Illinois had a mean year-round home range size of 0.098 $\pm$ 0.012 SE ha (Jike et al., 1988). Smaller home ranges were reported in Kansas and short-grass prairies of Colorado. Male prairie voles had mean home ranges of 0.037 $\pm$ 0.0029 SE and 0.011 ha and females had home ranges of 0.024 $\pm$ 0.0018 SE and 0.0073 ha in Kansas and Colorado, respectively (Swihart and Slade, 1989; Abramsky and Tracy, 1980). Female home range size decreases with increasing prairie vole density according to the following regression equation (Gaines and Johnson, 1982):

$$Y = -0.23X + 20.16$$

where, Y = home range length in meters and X= minimum number alive per 0. 8 ha grid.

Abramsky and Tracy (1980) found a similar correlation using both sexes according to the equation:

$$Y = -0.20X + 27.12$$

where, Y = home range length in meters and X= number of individuals per hectare.

Population Density

Population density was estimated in xeric prairie of Nebraska and was 25 to 35 voles per ha during the summer and 12 voles per hectare during winter (Meserve, 1971). In Illinois alfalfa fields, Carroll and Getz (1976) reported spring densities of 78 to 118 voles per ha while summer densities were reported as 81 to 104 voles per ha. Martin (1956) estimated seasonal densities for voles in Kansas grasslands. Summer densities ranged from 168 to 234 voles per ha, with winter densities being comparable at 160 to 197 voles per ha. Spring densities were the largest (203 to 247 voles per ha) while fall densities were smallest (94 to 123 voles per ha).

Population Dynamics/Survival

Female prairie voles can reach sexual maturity in about 35 d, males in 42 to 45 d (Gier and Cooksey, 1967, as cited in Stalling, 1990). Martin (1956) found in Kansas that females mature within about 6 wk in the summer, but may require 15 wk or more to mature if born in the fall. Male prairie voles tend to disperse from their natal site; approximately twice as many females as males mature near their birthplace (Boonstra et al., 1987). Populations tend to fluctuate with available moisture (Gier, 1967, as cited in Stalling, 1990). Mortality rates in prairie vole post-nestling juveniles and young adults are similar and higher than adult mortality rates; nestlings have the lowest mortality rate (Golley, 1961). Ambramsky and Tracy (1980) estimated the annual mortality rate for voles in Colorado short grass prairie to be 93 percent. Average life expectancy in the field is about 1 year, but can range up to 1.8 years in Kansas grasslands (Martin, 1956).

Reproduction/Breeding

Reproduction occurs throughout the year, but peaks from May to October, coinciding with high moisture availability (Martin, 1956; Keller, 1985). Gestation lasts approximately 3 wks. (Martin, 1956; Keller, 1985; Nadeau, 1985). Each female can produce several litters per year (Johnson and Johnson, 1982) with litter sizes ranging from 1 to 7 pups (Jameson, 1947). Mean litter sizes were 3.18 $\pm$ 0.24 SD, 3.4, and 4.25 in Kansas grasslands, unspecified areas in Kansas, and in Illinois, respectively (Martin, 1956; Jameson, 1947; Cole and Batzili, 1978). The young are weaned by about 3 weeks of age (Thomas and Birney, 1979).

Behavior and Social Organization

Prairie voles excavate underground nests that are used as nurseries, resting areas, and as shelter from severe weather (Klatt and Getz, 1987). They spend very little time away from this nest (Barbour, 1963). In thick vegetation, prairie voles move about in surface runways, and the number of runways is proportional to population density (Carroll and Getz, 1976).

Prairie voles are monogamous; a mated pair occupies the same home range (Thomas and Birney, 1979). Both sexes care for the young; paternal activities include runway construction, food caching, grooming, retrieving, and brooding the young (Thomas and Birney, 1979). Monogamous family units apparently defend territories against other family groups (Ostfeld et al., 1988; Johnson and Johnson, 1982; Thomas and Birney, 1979).

3.2.18 Meadow Vole (Microtus pennsylvanicus)[1]

Meadow voles are in the order Rodentia family Muridae (subfamily Arvicolinae). New World voles are small, herbivorous rodents that reside in all areas of Canada and the United States where there is good grass cover. Their presence is characterized by narrow runways through matted grasses. *Microtus* species are adapted to underground, terrestrial, and sometimes semiamphibious habitats (Johnson and Johnson, 1982). They are active by day and night, feeding mainly on shoots, grasses, and bark. Voles are prey for hawks and owls as well as several mammalian predators such as short-tailed shrews, badgers, and foxes (Johnson and Johnson, 1982; Eadie, 1952). The meadow vole (*Microtus pennsylvanicus*) makes its burrows along surface runways in grasses or other herbaceous vegetation.

Distribution

The meadow vole is the most widely distributed small grazing herbivore in North America and is found over most of the northern half of the United States. Meadow voles have been used in bioassays to indicate the presence of toxins in their foods (Kendall and Sherwood, 1975, cited in Reich, 1981; Schillinger and Elliot, 1966). Although primarily terrestrial, the meadow vole also is a strong swimmer (Johnson and Johnson, 1982).

Body Size and Weight

The meadow vole measures 8.9 to 13 cm in length (head and body) and has a 3.6-to 6.6-cm tail. They weigh between 20 and 40 g depending on age, sex, and location (see table). Mature males are approximately 20 percent heavier than females (Boonstra and Rodd, 1983). Meadow voles lose weight during the winter, reaching a low around February, then regain weight during spring and summer, reaching a high around August in many populations (see table; Iverson and Turner, 1974).

TABLE 3-39
Body Weights (g) of the Meadow Vole (*Microtus pennsylvanicus*)

Location	Age/Sex/Season	N	Mean	Range	Reference
Quebec, Canada	Adult male (summer)		40.0 ± 8.3		Brochu et al., 1983
	Adult female (summer)		33.4 ± 8.2		
Ontario, Canada	Adult male (spring)		52.4		Boonstra and Rodd, 1983
	Adult female (spring)		43.5		
Manitoba, Canada	Adults both				Anderson et al., 1984
	spring		26.0		
	summer		24.3		
	fall		17.0		
	winter		17.5		
s Indiana	Adult Male		35.5 ± 0.1		Myers and Krebs, 1971
	Adult Female		39.0 ± 0.3		
NS	neonate (both)		2.1	1.6 - 3.0	Hamilton, 1941
	neonate (both)		2.3 ± 0.1		Ines and Millar, 1981

[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

Food Habits and Diet Composition

Meadow voles consume green succulent vegetation, sedges, seeds, roots, bark, fungi, insects, and animal matter. They are agricultural pests in some areas, feeding on pasture, hay, and grain (Johnson and Johnson, 1982; Burt and Grossenheider, 1980). At high population densities, the meadow vole has been known to girdle trees, which can damage orchards (Byers, 1979, cited in Reich, 1981). In seasonal habitats, meadow voles favor green vegetation when it is available and consume other foods more when green vegetation is less available (Johnson and Johnson, 1982; Riewe, 1973; Getz, 1985). Although Zimmerman (1965) found some evidence of food selection, he found that meadow voles generally ate the most common plants in their habitat. Meadow voles living on prairies consume more seeds and fewer dicots and monocots than voles in a bluegrass habitat (Lindroth and Batzli, 1984). The meadow vole's large cecum allows it to have a high digestive efficiency of 86 to 90 percent (Golley, 1960). Coprophagy (eating of feces) has been observed in this species (Ouellete and Heisinger, 1980).

TABLE 3-40
Diet Consumption of the Meadow Vole (Microtus pennsylvanicus)

Location/Habitat	Dietary Composition	Spring	Summer	Fall	Winter	Reference
Illinois/bluegrass	dicot shoots	41	60	66	12	Lindroth and Batzli, 1984
	monocot shoots	50	26	9	40	
	seeds	1	9	1	13	(% volume; stomach contents)
	roots	0	1	12	34	
	fungi	6	4	10	0	
	insects	2	0	2	1	
Illinois/tallgrass prairie	dicot shoots	53	65	41	41	Lindroth and Batzli, 1984
	monocot shoots	23	29	12	5	
	seeds	7	1.0	16	36	(% volume; stomach contents)
	roots	4	0	6	17	
	fungi	12	1	20	0	
	insects	1	4	5	1	

Food Consumption Rate

Ognev (1958) reports the average food ingestion rate for meadow voles in Russia to range between 0.30 and 0.35 g/g-day. Dark et al. (1983) report average food ingestion for adult males to be 370 $\pm$ 20 cal/g-day on short days and 410 $\pm$ 10 cal/g-day on long days.

Using Eq. 6 and assuming a mean body weight of 0.033 kg (as calculated using the above table and adults) a food consumption rate of 0.14 kg/kg BW/day was estimated. To calculate a fresh weight of 0.72 kg/kg BW/day, Eq. 18 was used and a diet of 50 percent dicots and 50 percent monocots was assumed with water content of 79 and 85 percent, respectively was assumed (Table 3-4). (Note: If different body weights are used, then the rate should be recalculated.)

Water Consumption Rate

Ernst (1968) reports water ingestion rates for adults to be 0.21 $\pm$ 0.02 SE g/g-day. The estimated water consumption rate is 0.14 L/kg BW/day, using Eq. 19 and body weights from Anderson et al. (1984). (Note: If using different body weights, rate should be recalculated).

Soil Ingestion

Soil ingestion was estimated for the meadow vole by Beyer et al. (1994) at a rate of 2.4 percent of the diet

Respiration Rate

Literature-derived inhalation rates were not available, but were estimated using Eq. 21 and the average of body weights for male and female meadow voles presented above (Brochu et al., 1988; Boonstra and Rodd, 1983; Myers and Krebs, 1971). Rates were 1.03 and 1.05 m^3/kg BW/day for male and female adults, respectively. (Note: If using different body weights, then the rate should be recalculated)

Metabolism

In winter, *Microtus* species do not undergo hibernation or torpor; instead, they are active year round (Didow and Hayward, 1969; Johnson and Johnson, 1982). Behaviors that help meadow voles to maintain their body temperature include the use of burrows, runways, nests, and snow cover for insulation. They also can change when they are active; when temperatures exceed 20 ° C, meadow voles are most active at night (Getz, 1961b; Johnson and Johnson, 1982). In winter, meadow voles increase their brown fat content (a major site of thermoregulatory heat production). Mature individuals average 0.5 percent brown fat in summer, increasing to 1.7 percent in early winter; juveniles average 1.0 percent in the summer, increasing to 2.3 percent in the winter (Didow and Hayward, 1969). Voles undergo three molts: juvenile, post-juvenile, and adult. The timing varies by species (Johnson and Johnson, 1982). Adult Arvicolinae also undergo winter and summer molts (Johnson and Johnson, 1982).

A basal metabolic rate of 60 lO_2/kg BW/day was estimated in the lab by Wiegert (1961). Mirrison (1948) also did lab estimates of average daily metabolic rate (82.8 L O_2/kg/day). EPA (1993) estimated basal metabolic rate using equations from Boddington (1978) and free-living metabolic rate using equations from Nagy (1987). Body weights were from Anderson et al. (1984). Basal rates were 166 kcal/kg BW/day for males and 175 kcal/kg BW/day for females. For free-living adults, rates were 357 for males and 485 for females. Pearson (1947) estimated an average daily rate for males and females of 395 kcal/kg BW/day.

Habitat Requirements

The meadow vole inhabits grassy fields, marshes, and bogs (Getz, 1961a). Compared with the prairie vole, the meadow vole prefers fields with more grass, more cover, and fewer woody plants (Getz, 1985; Zimmerman, 1965). The meadow vole also tends to inhabit moist to wet habitats, whereas the prairie vole is relatively uncommon in sites with standing water (Getz, 1985).

Home Range

The area encompassed by a meadow vole's home range depends on season, habitat, population density, and the age and sex of the animal. Summer ranges tend to be larger than winter ranges, and ranges in marshes tend to be larger than ranges in meadows (Getz, 1961c; Reich, 1981). Home range size also declines with increasing population density (Getz, 1961c; Tamarin, 1977a). Female meadow voles defend territories against other females, whereas male home ranges are larger and overlap with home ranges of both sexes (Madison, 1980; Ostfeld et al., 1988; Wolff, 1985).

Estimates for summer home ranges in Virginia old fields were 0.019 ha for males and 0.0069 ha for females (Madison, 1980). In an alluvial bench in Montana, Douglas (1976) reported mean summer ranges of 0.014 ha and mean winter ranges of 0.0002 ha. Summer ranges in grassy meadows of Massachusetts for males averaged 0.083 ha while ranges for females averaged 0.037 ha (Ostfeld et al., 1988).

Population Density

Meadow vole population densities fluctuate widely from season to season and year to year, sometimes crashing to near zero before recovering in a few years to densities of several hundred per hectare (Boonstra and Rodd, 1983; Lindroth and Batzli, 1984; Getz et al., 1987; Myers and Krebs, 1971; Taitt and Krebs, 1985). Krebs and Myers (1974) noted population cycles of 2 to 5 years, whereas Tamarin (1977b) reported 3-to 4-year population cycles in southeastern Massachusetts. However, Getz et al. (1987) found no indication of multiannual abundance cycles in their three-habitat study (i.e., bluegrass, tallgrass prairie, and alfalfa) in east central Illinois. Meadow voles avoid short-tailed shrews (Fulk, 1972), and the vole population density decreases as the number of short-tailed shrews in the area increases (Eadie, 1952).

Population density in Ontario grasslands was reported by Boonstar and Rodd (1983) as 96 to 549 voles per ha. In Illinois bluegrass, densities were from 2 to 28 voles per ha (Lindroth and Batzli, 1984). Myers and Drebs (1971) reported densities in Indiana grasslands of 25 to 163 voles per ha. In Michigan, a grass sedge marsh had densities during the fall of 28 to 51 voles per ha, during the winter of 20 to 51 voles per ha, during the spring of 22 to 53 voles per ha, and during the summer of 38 to 64 voles per ha (Getz, 1961a).

Population Dynamics/Survival

As previously described, meadow vole populations often experience cyclic fluctuations in size with years of great abundance and years of severe crashes. Mortality rates are highest in post-nestling juveniles and young adults and lowest in nestlings (ages 1 to 10 d) (Golley, 1961). In south Michigan old fields, nestlings experienced 50 percent mortality, juveniles 61 percent, young adults 58 percent, adults 53 percent, and old adults 100 percent mortality (Golley, 1961). Beer and MacLeod (1961) determined a mean lifespan of only 2-3 months, while Johnson and Johnson (1982) reported a lifespan of less than 24 months. Myers and Krebs (1971) observed peak dispersal times among voles in Indiana grasslands to be in the fall and winter. In Massachusetts coastal fields, peak dispersal for females was in the summer and peadk dispersal for males occurred in the winter (Tamarin, 1977b). Dispersing meadow voles (predominantly young males) tend to weigh less than resident meadow voles (Boonstra et al., 1987; Myers and Krebs, 1971; Boonstra and Rodd, 1983; Brochu et al., 1988).

Reproduction/Breeding

Voles reach sexual maturity usually within several weeks after birth, with females maturing before males, but still continue to grow for several months (Johnson and Johnson, 1982). Meadow voles are polygynous (McShea, 1989). Males form a hierarchy in which the most dominant male voles breed (Boonstra and Rodd, 1983). In Manitoba, mating begins in early April and ends in mid-October (Mihok, 1984). Mating season in Michigan meadow voles is generally longer, but two peak mating periods from October to November and from April to June exist (Getz, 1960). Typical length of gestation is 21 days (Kenney et al., 1977).

Voles produce litters throughout the breeding season, the number of litters per season increases with decreasing latitude (Johnson and Johnson, 1982). Innes (1978) reported that litter size is independent of latitude or elevation. However, summer litters were, on average, 14 percent larger than litters produced during other seasons, and larger females produced larger litters (Keller and Krebs, 1970). Several litters are reared each year (Bailey, 1924) with sizes ranging from 1 to 11. Mean litter sizes of 3.82, 4.46, and 6.05 were reported for meadow voles breeding in Manitoba, Indiana, and Pennsylvania, respectively (Iverson and Turner, 1976; Corthum, 1967; Goin, 1943). Young are weaned at 21 days (Golley, 1961) and those from spring and early summer litters reached adult weight in about 12 wk (Brown, 1973).

Behavior and Social Organization

Meadow voles build runways in grasses and vegetation at the ground's surface and use the runways for foraging about 45 percent of the time, depending on weather and other factors (Gauthier and Bider, 1987). The meadow vole exhibits daytime activity where dense cover is available and becomes more crepuscular with less cover (Graham, 1968, cited in Reich, 1981). All *Microtus* species apparently do some burrowing, excavating underground nests that are used as nurseries, resting areas, and as shelter from severe weather (Johnson and Johnson, 1982). Nests are built with the use of dead grass in patches of dense, live grass; widened spaces, called forms, are used off main runways (Ambrose, 1973).

3.2.19 Muskrat (Ondatra zibethicus)[1]

The muskrat is in the order Rodentia, family Muridae. Water rats and muskrats are the most aquatic of this family of rodents, with most of their lives spent in or near bogs, marshes, lakes or streams. These two rodents feed mostly on aquatic vegetation. Only one species exists in each genus (Burt and Grossenheider, 1980). Muskrats feed primarily on aquatic plants. They are prey for hawks, minks, otters, raccoons, owls, red fox, dogs, snapping turtles, and water snakes (Bednarik, 1956; Errington, 1939a; Wilson, 1985), and are more

1 All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

vulnerable to predation during times of drought when low water levels leave their dens or lodges more exposed (Errington, 1939a).

Distribution

The muskrat is indigenous and common throughout most of the United States (except in the extreme southeast, central Texas, and most of California) and Canada (except in the extreme north) (Burt and Grossenheider, 1980). There are 16 recognized subspecies in North America (Perry, 1982). Of these, *O. z. zibethicus* (eastern United States, southeastern Canada), *O. z. osoyoosensis* (Rocky Mountains, southwestern Canada), and *O. z. rivalicius* (southern Louisiana, coasts of Mississippi, western Alabama, and eastern Texas) are most often studied.

Body Size and Weight

The muskrat measures 25 to 36 cm (head and body) with a 20-to 25-cm tail (Burt and Grossenheider, 1980), and adult weights can range from 0. 5 kg to over 2 kg. Willner et al. (1980) reported no sexual dimorphism, whereas Dozier (1950), Parker and Maxwell (1984), and others reported that males are slightly heavier than females. Muskrats tend to be larger and heavier in northern latitudes (Perry, 1982), although the smallest muskrats are found in Idaho (Reeves and Williams, 1956). Fat levels in adult males increase from spring through fall, and subsequently decrease from winter to spring (Schacher and Pelton, 1975). In non-pregnant females, fat levels decrease from winter through summer; in pregnant females, body fat increases from spring to summer (Schacher and Pelton, 1975).

TABLE 3-41
Body Weights (g) of the Muskrat (*Ondatra zibethicus*)

Location	Sex/Season	N	Mean	Range	Reference
New York	male (winter)		1,480	1,400 - 1,520	Dozier, 1950
	female (winter)		1,350	1,300 - 1,400	
e Tennessee	male (winter)		1,326 $\pm$ 45.9 SE		Schacher and Pelton, 1978
	female (winter)		1,221 $\pm$ 54.2SE		
Nebraska, nc Kansas	male (winter)		1,180	730 - 1,550	Sather, 1958
	female (winter)		1,090	770 - 1,450	
Idaho	male (spring)		909		Reeves and Williams, 1956
	female (spring)		837		
Iowa	neonate		21.3	16-28	Errington, 1939b
New York	neonate			20-25	Dean, 1957
Iowa	at weaning		200		Errington, 1939b
New Brunswick, Canada				112-184	Parker and Maxwell, 1980

Food Habits and Diet Composition

Muskrats are primarily herbivorous, but some populations are more omnivorous (Dozier, 1953; Errington, 1939b). Muskrats usually feed at night, diving to gnaw on aquatic vegetation growing near their houses (Dozier, 1953; Johnson, 1925; Perry, 1982). The roots and basal portions of aquatic plants make up most of the muskrat's diet, although shoots, bulbs, tubers, stems, and leaves also are eaten (Dozier, 1950, 1953; Willner et al., 1980; Svihla and Svihla, 1931). Marsh grasses and sedges (Svihla and Svihla, 1931) and cattails (Johnson, 1925; Willner et al., 1975) seem to be important muskrat foods; in Maryland, green algae is also important (Willner et al., 1975). Although muskrats forage near their dens or lodges, they show preferences for some plant species (e. g., cattails, bulrushes) over others (Bellrose, 1950). Muskrats are a major consumer of marsh grasses (Kiviat, 1978). They also dig for food on lake and pond bottoms (Bailey, 1937; Dozier, 1953; Hanson et al., 1989). Among the animals that muskrats consume are crayfish, fish, frogs, turtles, and young birds (Errington, 1939b; Johnson, 1925; Willner et al., 1980). Mollusks are an important component of the diet of some populations (Convey et al., 1989; Neves and Odom, 1989; Parmalee, 1989; Willner et al., 1980). Young muskrats feed more on bank vegetation than do adults (Warwick, 1940, cited in Perry, 1982).

TABLE 3-42
Diet Consumption of the Muskrat (*Ondatra zibethicus*)

Location/Habitat	Dietary Composition	Summer	Winter	Reference
ne United States/NS	cattail		25-50	Martin et al. 1951
	bulrush		10-25	
	burreed		5-10	(rough approximation of % diet;
	waterstarwort		2-5	stomach contents)
	pondweed		2-5	
	arrowhead		2-5	
	corn		2-5	
Somerset County, Maryland/brackish marsh	cattail	59		Willner et al., 1975
	rush	17		
	millet	8		(% of diet; stomach contents)
	algae	5		
	grass	4		
	cord grass	4		
	seeds	2		
	other	3		
Montgomery County, Maryland/freshwater	green algae	77		Willner et al., 1975
	3-square rush	8		
	switchgrass	8		(% of diet; stomach contents)
	soft rush	4		
	water willow	2		
	grass	1		
	other	<1		

Food Consumption Rate

Svihla and Svihla (1931) reported food consumption rates of 0.34 g/g-day for captive muskrats in Louisiana fed a diet of greens (*Panicum hemitomum, P. virgatum* and *Spartina patens*) and a rate of 0.26 g/g-day when fed a diet of greens and corn. Using Eq. 5 a food consumption rate of 0.068 kg/kg BW/day can be calculated assuming a mean body weight of 1.04 kg (as calculated using the above table and adults). Equation 18 can then be used to calculate a fresh weight of 0.43 kg/kgBW/day assuming a diet of 77 percent algae and 33 percent dicots (Willner et al., 1975) with respective water contents of 84 and 79 percent (Table 3-4). (Note: if using different body weights, then the rate should be recalculated).

Water Consumption Rate

No data on water consumption rate in muskrats was available in the literature reviewed. Water consumption rates for adult males and females have been estimated at 0.97 and 0.98 L/kg BW/day respectively, using Eq. 19 and body weights from Sather (1958). (Note: If using different body weights, then the rate should be recalculated.)

Soil Ingestion

No soil ingestion data was available in the reviewed literature. Soil ingestion is expected to be high because muskrats primarily feed on the roots and basal portions of aquatic plants (Dozier, 1950, 1953; Willner et al., 1980; Svihla and Svihla, 1931). Raccoons are also known to forage in sediments for aquatic prey (Palmer and Fowler, 1975). Therefore, it was assumed that soil ingestion for raccoons (9.4 percent of the diet) reported in Beyer et al. (1994) would be representative of that for muskrats.

Respiration Rate

No literature-derived data for respiration rates in muskrats were available. A rate of 0.53 m^3/kg BW/day for males and 0.54 m^3/kg BW/day for females was estimated using Eq. 21 and body weights from Sather (1958). (Note: If using different body weights, then the rates should be recalculated.)

Metabolism

Fish (1982) reports metabolic activity for muskrats in 25 °C water as 101 kcal/kg BW/day while floating and 182 kcal/kg BW/day while swimming. These values are equal to 21 L O_2/kg BW/day while floating and 38 L O_2/kg BW/day while swimming (Fish, 1982). Basal metabolism for adults of both sexes is estimated to be 71.6 kcal/kg BW/day using the equation in Boddington (1978) and body weights from Sather (1958). Free-living adult metabolic rates were estimated at 213 kcal/kg-d (range 90-505) for adult males and 216 kcal/kg-d (range 91-513) for adult females using the equation in Nagy (1987) and body weights from Sather (1958). (Note: if body weights are different, then the rate should be recalculated.)

Active year-round (Kiviat, 1978), muskrats usually begin their annual molt in the summer, with fur reaching its minimum density during August (Willner et al., 1980). Muskrats use their dens or lodges to insulate themselves from summer heat and winter cold (O'Neil, 1949; Willner et al., 1980). During extreme cold, muskrats may freeze to death if they are unable to plug their den entrances (Errington, 1939a).

Habitat Requirements

Muskrats inhabit saltwater and brackish marshes and freshwater creeks, streams, lakes, marshes, and ponds (Dozier, 1953; Johnson, 1925; Kiviat, 1978; O'Neil, 1949). Muskrats that live along the banks or shores of waterways generally excavate dens in the banks, whereas muskrats living in ponds with ample plant material construct lodges (Johnson, 1925; Perry, 1982). When available, bank dens seem preferred over constructed lodges (Johnson, 1925).

Home Range

Muskrats have relatively small home ranges that vary in configuration depending on the aquatic habitat (Perry, 1982; Willner et al., 1980). Using radiotelemetry, MacArthur (1978) found muskrats within 15 m of their primary welling 50 percent of the time and only rarely more than 150 m. Mathiak (1966) reported other experiments showing that muskrats remain close to their dwellings. Home range reported by Proulx and Gilbert (1983) in Ontario were 0.17 ha during the summer in a marsh, 0.048 ha during the early summer and 0.11 ha in the late summer in a bay. Neal (1968) observed a home range of 0.17 ha for both males and females in marsh areas of Iowa.

In the summer, muskrats often change the use of their home range in response to water levels; during droughts they will move if the area around the house dries up, which can lead to intense aggression in the more favorable habitat (Errington, 1939a). Usually only a minor proportion of drought-evicted muskrats can find new homes (Errington, 1939a). In the winter, droughts can result in severe mortality (Errington, 1937a).

Population Density

Bellrose and Brown (1941, cited in Perry, 1982) concluded that cattail communities support more muskrat houses than other plant types in the Illinois River valley. Cattail communities also support high densities of muskrats in other areas (Errington, 1963; Dozier, 1950). In pond and lake habitats, shoreline length is a more important factor than overall habitat area in determining muskrat density (Glass, 1952, cited in Perry, 1982). Many investigators estimate muskrat densities by counting the number of houses or push-ups and multiplying by a factor ranging from 2.8 (Lay, 1945, cited in Boutin and Birkenholz, 1987) to 5.0 (Dozier et al., 1948), although this method is questionable (Boutin and Birkenholz, 1987).

Population densities in open water, riverine habitats of Iowa were 9.3 muskrat per ha in the spring, 2.6 muskrat per ha in the summer, and 6.3 muskrat per ha in the fall (Clay and Clark, 1985). In Virginia, males had densities of 18.7 muskrat per ha in fringe marshes, and 2.1 per ha in marsh areas (Halbrook, 1990). O'Neil (1949) reported 28.3 muskrats per ha in marsh areas of Louisiana, although densities ranged from 1-74 muskrat per ha. Brooks and Dodge (1986) reported densities along rivers in Pennsylvania (23 per km) and Massachusetts (48 per km).

Population Dynamics/Survival

The age at first breeding varies but usually occurs during the first spring after birth (Errington, 1963; Perry, 1982). Southern populations produce more litters but with fewer pups in each than do northern populations (Boyce, 1977; Perry, 1982; see table). Muskrats in lower quality habitats have both smaller litter sizes and fewer litters than muskrats in better quality areas (Neal, 1968). They disperse in the spring to establish breeding territories or to move into uninhabited areas (Errington, 1963). Muskrat population cycles of 5, 6, and 10 years have been reported (Butler, 1962; Willner et al., 1980). Perry (1982) summarized several studies that reported cycles ranging from 10 to 14 years or more. Butler (1962) found that muskrats follow a 10-yr cycle in most parts of Canada. Annual mortality was reported as 87 percent for adults and 90 percent for juveniles in Iowa riverines (Clay and Clark, 1985). Schwartz and Schwartz (1959) reported juvenile mortality of 67 percent in Missouri. Longevity was reported as less than 5 years by Proulx and Gilbert (1983).

Reproduction/Breeding

In southern parts of their range, muskrats breed throughout the year, with late fall and early spring peaks (O'Neil, 1949; Svihla and Svihla, 1931; Wilson, 1955). In northern latitudes, breeding occurs only in the spring and summer, with first litters born in late April or early May (Mathiak, 1966; Beer, 1950b; Errington, 1937b; Gashwiler, 1950). The muskrat has about 2 to 6 litters per year with a gestation period of 29-30 days (Errington, 1937b; Gashwiler, 1950). Reported mean number of liters per year were 1.7, 2.1, and 5 to 6 in Idaho, Maine, and Louisiana, respectively (Reeves and Williams, 1956; Gashwiler, 1950; O'Neil, 1949). Litter size also varied by region with muskrats in Louisiana and Virginia marshes having 3.46 and 4.65 pups per year (O'Neil, 1949; Halbrook, 1990) compared to 7.1 and 7.3 pups per year in Iowa and Wisconsin (Clay and Clark, 1985; Mathiak, 1966). Errington (1937b) found that postpartum estrus occurs in the muskrat, and suggested that the period between litters is about 30 d. Neonates are almost hairless but by age 2 wk are covered with fur and able to swim (Errington, 1963). Weaning occurs at approximately 28 days (range 21-30 d; Errington, 1939a).

Behavior and Social Organization

Muskrats are solitary or form breeding pairs that remain in a home range exclusive of other pairs (Errington, 1963; Proulx and Gilbert, 1983). They are territorial, particularly during peak reproductive activity, with their houses usually spaced at least 8 m apart (Johnson, 1925; Sather, 1958; Trippensee, 1953). They build two different types of houses: a main dwelling and a feeding house (feeder) that is smaller than the main house (Dozier, 1953; Johnson, 1925; Sather, 1958). The feeder provides protection from the elements and predators when feeding in prime foraging areas, as well as access to oxygen during frozen conditions. The house provides a dry nest and stable temperatures. Muskrats usually forage within 5 to 10 m of a house (Willner et al., 1980). In the winter, muskrats build pushups, which are cavities formed in 30 to 46 cm high piles of vegetation pushed up through holes in the ice of a marsh (Perry, 1982). Muskrats use pushups as resting places during frozen conditions to minimize their exposure to cold water (Fuller, 1951).

3.3.20 Northern Grasshopper Mouse (*Onychomys leucogaster*)[3]

The northern grasshopper mouse is a member of the order Rodentia, family Cricetidae. The genus *Onchomys* includes two recent species, *O. leucogaster* and *O. torridus* which can occur together, but remain ecologically isolated due to differing habitat preferences (Gennaro, 1968; Pinter ,1971). In general appearance, grasshopper mice resemble deer mice (*Peromyscus* spp.), but are of shorter and heavier build.

3 New species accounts compiled for ARAMS.

Distribution

O. leucoaster live in mesic areas at higher elevations and extend from Saskatchewan, Alberta and Manitoba to extreme northern Mexico, west into northeastern California and central Oregon, and east to western Minnesota and Iowa (McCarty, 1978).

Body Size and Weight

The northern grasshopper mouse is a short-tailed, stocky mouse. In general, the total length of the mouse is 119 to 190 mm with a tail length of 29 to 62 mm, about half the length of the body (McCarty, 1978). One mouse was noted to weigh 22 g after eating a 2.2 g white-footed mouse (Bailey and Sperry, 1929).

TABLE 3-43
Body Weights (g) for the Northern Grasshopper Mouse (*Onychomys leucogaster*)

Location	Sex	N	Mean	Reference
Laboratory	Males	11	42.4 g	Harriman, 1973
	Females	11	38.9 g	
	Mixed (17 days old)	60	17 g	

[a] Not stated

Food Habits and Diet Composition

The northern grasshopper mouse feeds mainly on arthropods but occasionally feeds on small mammals, forbs, grasses, sedges, and seeds. Diet seems to change according weather, with warm-weather diets consisting of animal and plant matter and cold-weather diets consisting of animal fat (Jahoda, 1970a). Animal material contributed 88.9 percent of the total food consumed and cultivated grains represented less than 5 percent of the total in the stomach contents of field-trapped grasshopper mice (Bailey and Sperry, 1929). Egoscue (1960) determined in laboratory tests that food preferences were grasshoppers, tenebrionid beetles, and all species of sympatric, cricetid and heteromyid rodents. The diet composition of northern grasshopper mice is shown in Table 3-44.

Food Consumption Rate

It was noted that in one study a mouse was found to eat its own weight (approx. 22 g) in 24 hours (Bailey and Sperry, 1929). Another study noted an average consumption of 51.36 mg/g BW/day or 0.051 kg/kg BW/day when given a self-selection array of foodstuffs over 60 days (Harriman, 1973). Using Eq. 6 and assuming a mean body weight of 0.041 kg (as calculated using the above body weight table and adults) a food consumption rate of 0.12 kg/kg BW/day was estimated. To determine a fresh weight (0.38 kg/kg BW/day) a diet of 87 percent insects, 7 percent grasses, and 4 percent seeds (Hoffmeister, 1986) with respective water contents of 69, 79, and 9.3 percent (Table 3-4). (Note: If using other body weight values, then the rate should be recalculated).

TABLE 3-44
Diet Composition of Northern Grasshopper Mouse (*Onychomys leucogaster*)

Location	Prey Taxon	Percent Volume	Reference
Colorado	Plant matter	25.3	McCarty, 1978
	Animal matter	73.9	
Colorado	Arthropod	87	Hoffmeister, 1986
	Grasses and forbs	7	
	Seed material	4	
	Mammal/reptile remains	1	
Mixed locations (90 specimen from 13 states)	Orthoptera	38.76	Bailey and Sperry, 1929
	Coleoptera	20.73	
	Lepidoptera	17.04	
	Mammalia	3.09	
	Reptilia	0	
	Misc. Animal food	3.25	
	Hymenoptera	2	
	Diptera	0.7	
	Arachnida	0.5	
	Hemiptera	0.05	
	Vegetable food	11.13	
Colorado (July – August)	Coleoptera adults	36.5	Flake, 1973
	Coleoptera larvae	16.4	
	Grasshoppers	18.1	
	Lepidoptera larvae	2	
	Spiders	2.9	
	Vertebrates	1.8	
	Seeds	3.5	
	Forbs	5.2	
	Grasses and sedges	6.2	
	Shrubs	0.6	

Water Consumption Rate

The grasshopper mouse most likely obtains water from dew and food (especially from insect larvae and animal fat) in wild, although they require water in laboratory conditions (Zeiner et al., 1990). In a laboratory study of mice on a standard laboratory diet versus mice fed on a self-selection schedule, water consumption rates varied. Mice that were allowed to select their own food had a lower water consumption rate (9.0 $\pm$ 1.9 mL/100 g/day or 0.09 L/kg BW/day) than those fed the standard diet (13.4 $\pm$ 2.5 mL/100 g/day or 0.13 L/kg BW/day; Harriman, 1973). Using Eq. 19 and a mean body weight of 0.041 kg, a water consumption rate of 0.14 L/kg BW/day can be estimated. ((Note: If using other body weight values, then the rate should be recalculated).

Soil Ingestion

No information on soil ingestion rate was found in literature for the northern grasshopper mouse. However, Talmage and Walton (1993) reported a soil ingestion rate of 13 percent of the diet for short-tailed shrews. Because short-tailed shrews and northern grasshopper mice have a similar diet, it is likely that the soil ingestion rates of these two species are similar.

Respiration Rate

No information on respiration rate was found in the literature. Using Eq. 21 and a mean body weight of 0.41 kg, a rate of 1.03 m^3/kg BW/day can be estimated (Note: If using other body weight values, then the rate should be recalculated).

Metabolism

No information concerning metabolism in northern grasshopper mice was found in the literature reviewed.

Habitat Requirements

Habitat requirements include low to moderate canopy-coverage and friable soil deep enough for burrowing (Zeiner et al., 1990). Additionally, the northern grasshopper mouse may require silty soils, which allow for frequent dustbathing (Egoscue, 1960). Burrows are commonly found in sand drifts at the base of bushes (Hoffmeister, 1986).

Home Range

The northern grasshopper mouse has an unusually large home range, which is associated with its predatory lifestyle. Blair (1953) found that the home range of four adult males averaged 2.3 ha (5.8 ac).

Population Density

Local populations of *O. leucogaster* are likely not regulated by avian or mammalian predators (McCarty, 1978). Although it is believed that they have low population densities, Baily and Sperry (1929) suggest they may just be difficult to catch. Northern grasshopper mice are not colonial, do not use definite runways, and, as hunters, they may wander quite far. However, large numbers have been trapped in areas with favorable habitat.

Population Dynamics/Survival

Northern grasshopper mice have lived up to four years under laboratory conditions though this life span is unlikely outside of captivity (Egoscue, 1960; Pinter, 1970). Studies on population dynamics are lacking probably due to the relatively low population densities in the wild or to the difficulty in trapping grasshopper mice (Baily and Sperry, 1929). The occurrence of adults as isolated individuals or male-female pairs has been suggested (Egoscue, 1960).

Reproduction/Breeding

Breeding occurs from February to August and peaks during June through August. Nonlactating females have a 29-32 day gestation period while lactating females have a 32-38 day gestation period (Egoscue, 1960). Females can produce one to twelve litters per year (Egoscue et al., 1970) but average 5.1 with an average litter size of 3.5 young (Zeiner et al., 1990). Other values for average litter size include 3.7 (Pinter, 1970), 3.54 (range 1 to 6; Egoscue, 1960), 3.2 (Scudder et al., 1967), and 3.8 (Ruffer, 1964).

Shallow, grass-lined, u-shaped nest burrows with an average length of 48 cm are typically excavated by a male-female pair (Ruffer, 1965). Occasionally, abandoned burrows of small mammals serve as the nest burrow (Zeiner et al., 1990).

Behavior and Social Organization

O. leucogaster is nocturnal and is active year-round with reduced nocturnal activity during full moons and during heavy, prolonged rainfall (Zeiner et al., 1990). Mice are most active during periods of heavy cloud cover with light or intermittent rains and when the moon is below the horizon (Jahoda, 1970b, 1973).

Evidence suggests that they are territorial, attacking intruding mice (Clark, 1962a, 1962b; Ruffer, 1968). Intraspecific encounters between adults have been noted and occur with the dominant animal chasing the subordinate and pouncing at its back repeatedly. The subordinate was commonly killed with a bite through the neck at the base of the skull (Ruffer, 1968).

Burrows are essential for protection from the high daytime temperatures common in xeric habitats. Four types of burrows have been observed including retreat burrows, nest burrows, cache burrows, and miscellaneous burrows (Hoffmeister, 1986; Ruffer, 1965).

3.2.21 Deer Mouse *(Peromyscus maniculatus)*[1]

Deer mice are in the order Rodentia, family Muridae (Genus *Peromyscus*). New World mice (family Muridae) are small, ground-dwelling rodents that live in a large variety of habitats including woodlands, prairies, rocky habitats, tundra, and deserts. All are nocturnal and are preyed on by owls, hawks, snakes, and carnivorous mammals. Most species eat primarily seeds, but some also regularly eat small invertebrates. Many species store food.

Distribution

The genus *Peromyscus* is the most widespread and geographically variable of North American rodents (MacMillen and Garland, 1989). The deer mouse is primarily granivorous and has the widest geographic distribution of any *Peromyscus* species (Millar, 1989; Brown and Zeng, 1989). It is resident and common in nearly every dry-land habitat within its range, including alpine tundra, coniferous and deciduous forest, and grasslands as well as deserts. There are many recognized subspecies or races of the deer mouse associated with different locations or insular habitats, including *artemisiae*, *austerus*, *bairdii*, *balaclavae*, *blandus*, *borealis*, *carli*, *cooledgei*, *gambelii*, *gracilis*, *labecula*, *maniculatus*, *oreas*, *nebrascensis*, *nubiterrae*, *rufinus*, and *sonoriensis* (MacMillen and Garland, 1989; Millar, 1982).

Body Size and Weight

Deer mice range from 7.1 to 10.2 cm in length, with a 5.1 to 13 cm tail, and adults weigh from 15 to 35 g (Burt and Grossenheider, 1980; see table). Body size varies somewhat among

[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

populations and subspecies throughout the species' range. Body weight also varies seasonally, being lower in autumn and winter and a few grams higher in spring and summer (Zegers and Merritt, 1988). There may (Fleharty et al., 1973) or may not (Millar and Schieck, 1986) be seasonal differences in fat content.

TABLE 3-45
Body Weights (g) of the Deer Mouse (*Peromyscus maniculatus)*

Location	Sex	N	Mean	Range	Reference
North America	Adult Male		22		Millar, 1983
	Adult Female		20		
NS (*austerus*)	Adult Male		15.7		Fordham, 1971
	Adult Female		14.8		
NS (*blandus*)	Adult Male		22.3		Dewsbury et al., 1980
	Adult Female		21.1		
New Hampshire	Adult both		19.6 ± 0.71		Schlesinger and Potter, 1974
NS (*borealis)* lab	Adult female, nonbreeding		20.3 ± 0.42		Millar and Innes, 1983
	Adult female gestating		31.5 ± 0.43		
	Adult female lactating		24.5 ± 0.37		
North America	neonate		1.8	1.6-2.8	Millar, 1989
Alberta, Canada	neonate		1.7 ± 0.02		Millar, 1989
North America	at weaning		8.8	7.7-11.2	Millar, 1989
Northwest Territories, Canada	at weaning		9.3 + 0.10		Millar, 1979

Food Habits and Diet Composition

Deer mice are omnivorous and highly opportunistic, which leads to substantial regional and seasonal variation in their diet. They eat principally seeds, arthropods, some green vegetation, roots, fruits, and fungi as available (Johnson, 1961; Menhusen, 1963; Whitaker, 1966). The nonseed plant materials provide a significant proportion of the deer mouse's daily water requirements (MacMillen and Garland, 1989). Food digestibility and assimilation for most of their diet have been estimated to be as high as 88 percent (Montgomery, 1989). Deer mice may cache food during the fall and winter in the more northern parts of their range (Barry, 1976; Wolff, 1989). They are nocturnal and emerge shortly after dark to forage for several hours (Marten, 1973).

TABLE 3-46
Diet Consumption of the Deer Mouse (*Peromyscus maniculatus*)

Location/Habitat	Dietary Composition	Spring	Summer	Fall	Winter	Reference
Virgina (n*ubiterrrae*)/oak-maple-hickory forest	nuts/seeds		0	24	23	Wolff et al., 1885
	arthropods		56	30	46	
	Lepidopt. larvae		4	trace	2	(% frequency of occurrence; stomach contents)
	Lepidopt. adults		3	26	7	
	green veg.		5	12	18	
	fungus		7	trace	1	
	fruit		25	4	1	
	unknown		1	4	3	
Indiana/several habitats	Lepidopt. larvae	20.6	34.5	16.7	4.8	Whitaker, 1966
	corn	4.1	4.2	3.2	8.7	
	misc. veg.	15.8	3.1	8.0	13.4	(% volume; stomach contents)
	wheat seeds	6.5	1.6	3.2	23.7	
	unident. seeds	5.4	5	8.8	8.3	
	green veg.	7.6	0	4.3	3.7	
	Echinochloa seeds	0	1.2	6.4	0	
	Coleoptera	3.9	5.3	5.1	1.4	
	soybeans	13.4	3.1	6.9	10.7	
	Heymiptera	1.3	2.7	4.2	0.9	
Colorado/short grass prairie	beetles	14.6	23.8	9.4	4.9	Flake, 1973
	grasshoppers	6.4	4.2	6.4	2.5	
	leafhoppers	13.3	1.8	1.9	2.5	(% volume by a ranking method; stomach contents).
	Lepidopterans	21.7	12.7	1.5	1.8	
	spiders	2.6	2.7	2.5	0.3	
	seeds	22.5	25.9	56.8	65.4	
	forbs	4.7	10.0	5.6	4.3	
	grasses and sedges	4.0	2.6	2.8	4.8	
	shrubs	3.8	1.4	0.8	2.6	

Food Consumption Rate

Based on laboratory studies the food consumption rates of nonbreeding females are between 0.18 and 0.19 g/g-day (Cronin and Bradley, 1988; Millar and Innes, 1983; Millar, 1979). Lactating females were found to have food ingestion rates of between 0.38 and 0.45 (Millar and Innes, 1983; Millar, 1979). In laboratory studies adult males were found to have a food consumption rate of 0.22 g/g-day (Cronin and Bradley, 1988). Similar consumption rates were found for juvenile males, with an ingestion rate if 0.21 in the laboratory (Nelson and Desjardins, 1987). Additionally, several studies have indicated that daily food consumption in female deer mice increases over 15 percent during early pregnancy and more than doubles during lactation (Glazier, 1979; Millar, 1975, 1978, 1979, 1982, 1985; Millar and Innes, 1983; Stebbins, 1977).

Using Eq. 5 and assuming a mean body weight of 0.021 kg (as calculated using adult weights in above table) a food consumption rate of 0.14 kg/kg BW/day was estimated. Equation 18 was used to estimate a fresh weight of 0.34 kg/kg BW/day assuming a diet of 58.6 percent terrestrial invertebrates, 22.5 percent seeds, and 12.5 percent grasses (Flake, 1973) with respective water contents of 61, 9.3 and 79 percent (Table 3-4). (Note: if different body weights are used, then the rate should be recalculated.)

Water Consumption Rate

The water consumption rate for adults of both sexes was determined to be 0.19 g/g-day in laboratory studies (Ross, 1930, Dice 1922). Laboratory studies found that juvenile males ingested water at a rate of 0.34 g/g-day (Nelson and Desjardins, 1987), a rate twice as high as the estimated 0.15 L/kg BW/day based on Eq. 19 and body weights from Millar (1989). (Note: If using different body weights, then the rate should be recalculated.)

Soil Ingestion

No literature data were available on soil ingestion in deer mice; however, Beyer et al. (1994) estimated a soil ingestion of <2.0 percent of the diet for the white-footed mouse. This rate is likely to be comparable to that of the deer mouse because of the similarity in eating habits.

Respiration Rate

No literature data for inhalation rates in deer mice were available. Therefore, inhalation rates of 1.17 m^3/kg BW/day for males and 1.19 m^3/kg BW/day for females were estimated using Eq. 21 and body weights from Millar (1989). (Note: If using different body weights, then the rate should be recalculated.)

Metabolism

The deer mouse has a metabolic rate about 1. 3 times higher than the other species in the genus (MacMillen and Garland, 1989; Morris and Kendeigh, 1981). Stebbins et al. (1980) reported average daily metabolic rates for male deer mice in laboratory conditions. Its metabolic rate is substantially higher in winter than in summer (Morris and Kendeigh, 1981; Stebbins, 1978; Zegers and Merritt, 1988). Outside the thermoneutral zone (25 to 35 ° C), metabolic rate varies according to the following equation:

$$V_{O2} = 0.116 - 0.003(T_a) + 0.0304\,(V^{0.5})$$

where, V_{O2} = volume oxygen consumed (ml/g-min); T_a = ambient temperature; and V = wind speed (Chappell and Holsclaw, 1984).

Deer mice can enter torpor (body temperature, 19 to 30 °C)to reduce metabolic demands in the winter and also in response to brief food shortages (Tannenbaum and Pivorun, 1988, 1989). The deer mouse uses nonshivering thermogenesis (NST) to quickly awaken from torpor and to maintain body temperature during the winter (Zegers and Merritt, 1987). The deer mouse may burrow in soils to assist thermoregulation; one study measured the burrow dimensions to be 24 cm deep (range 13 to 50 cm) and 132 cm long (range 30 to 470 cm) (Reynolds and Wakkinen, 1987).

Resting metabolic rate for females in North America was estimated at 50 L O_2/kg BW/day (MacMillen and Garland, 1989). In Alberta, Stebbins et al. (1980) estimated the average daily rate for males during winter (668 kcal/kg BW/day), spring (623 kcal/kg BW/day), and for summer (360 kcal/kg BW/day). For free living adults of both sexes a winter rate of 790 kcal/kg/day and a summer rate of 592 kcal/kg BW/day were estimated in an Illinois lab (Morris and Kendeigh, 1981). Free living metabolic rates of 547 kcal/kg BW/day for males and 574 kcal/kg BW/day for females can be estimated using equations from Nagy (1987) and body weights from Millar (1989). (Note: if body weights are different, then the rate should be recalculated.)

Habitat Requirements

Deer mice inhabit nearly all types of dry-land habitats within their range: short-grass prairies, grass-sage communities, coastal sage scrub, sand dunes, wet prairies, upland mixed and cedar forests, deciduous forests, ponderosa pine forests, other coniferous forests, mixed deciduous-evergreen forests, juniper/piñon forests, and other habitats (Holbrook, 1979; Kaufman and Kaufman, 1989; Ribble and Samson, 1987; Wolff and Hurlbutt, 1982). Few studies have found microhabitat features that distinguish the deer mouse, and some studies have come to different conclusions regarding habitat structure preferences (Ribble and Samson, 1987). For example, Vickery (1981) found that deer mice appeared to prefer areas with moderate to heavy ground and mid-story cover to more open ground areas, whereas others have found more deer mice in more open than in more vegetated areas (see Kaufman and Kaufman, 1989).

Home Range

Deer mice tend to occupy more than one nest site, most frequently in tree hollows up to 8 m from the ground (Wolff and Durr, 1986) but also among tree roots and under rocks and logs (Wolff and Hurlbutt, 1982; Wolff, 1989). At low densities, home ranges are maintained by mutual avoidance, but at higher densities, females may defend a core area or territory (Wolff, 1989). The home range of female deer mice encompasses both their foraging areas and their nests. Male home ranges are larger and overlap the home ranges of many females (Cranford, 1984; Taitt, 1981; Wolff, 1985a, 1986; Wolff et al., 1983). Cranford (1984) estimated a home range in snowfree subalpine Utah meadows during summer of 0.039 ha for males and 0.027 for females. In contrast, home ranges for snowbound subalpine meadows were 0.019 for males and 0.014 for females. In Virginia, Wolff (1985a) estimated a home range of 0.058 for males and 0.061 for females inhabiting a mixed deciduous forest. Bowser and

Smith (1979) reported ranges of 0.1 ha for males and 0.075 ha for females in ponderosa pine forests in Oregon and 0.128 ha for males and 0.094 ha for females in desert areas of Idaho.

Population Density

Population density varies considerably over space and time and is often positively correlated with food abundance (Taitt, 1981; Wolff, 1989), moisture content of plants (Bowers and Smith, 1979), and vegetative cover (van Horne, 1982) as well as season (Montgomery, 1989; Taitt, 1985). Interspecific competition also can play a role in determining population densities (Kaufman and Kaufman, 1989).

Brown and Zeng (1989) reported a population density in the desert of Arizona of 0.19 mice per ha. In subalpine meadows of Colorado a summer density of 2.8 mice/ha for adult males and females was reported (Vaughn, 1974). Cranford (1984) studies deer mice in the subalpine meadows of Utah and observed differences in summer and winter population densities, with 12.8 to 22.4 mice/ha in summer compared to only 3.4 to 8.4 mice/ha in winter. Sullivan (1979) reported a population density in British Columbia of 12.7 to 45.5 mice/ha, while densites in Montana were 3.9 to 28 mice/ha (Metzgar, 1979).

Population Dynamics/Survival

Although laboratory and field studies have demonstrated that females can produce their first litter by 3 months of age, females of the more northern populations do not mature under natural conditions until the spring after the year of their birth. The largest litters are produced in northwestern North America. Pups wean within about 3 weeks, and females may have up to four litters per year in the more southern parts of the species' range (Millar, 1989). Peak dispersal in young male deer mice in Vancouver occurs in spring (Fairbairn, 1977). Mortality rates are high, and most deer mice live for less than 1 year (Millar and Innes, 1983).

Mortality rates were reported by Millar and Innes (1983) for winter and summer in alpine habitats of Alberta. Winter mortality rates for adult females was 100 percent but only 33 percent for males. Juveniles had winter mortality rates of 56 percent for females and 70 percent for males. Summer rates for adults of both sexes were 20 percent per 2 weeks, and 19 percent for two weeks for juveniles of both sexes.

Reproduction/Breeding

Dramatic differences in the timing of the mating season have been recorded. For example, the mating season in Massachusetts is from April to August (Drickamer, 1978), compared to mating seasons of November to April, March to October, and May to August in Texas, Virginia, and California, respectively (Blair, 1958; Wolff, 1985b; Dunmire, 1960). The duration of the reproductive season varies with latitude and longitude according to the regression equation:

$$Y = -33.0 + 2.79\,X + 0.0748\,Z - 0.0370\,X^2$$

where, Y = duration of the breeding season in weeks, X = latitude, and Z = longitude (r = 0. 58; Millar, 1989).

Lactating females have longer gestation periods than non-lactating females with the average gestation for non-lactating deer mice in North America being 23.6 days and 26.9 days for lactating mice (Millar, 1989). This trend was also reported in other studies where non-lactating and lactating deer mice had gestation lengths of 22.4 $\pm$ 0.1 SE and 24.1 $\pm$ 0.3 SE days in Kansas (Svendsen, 1964), and 25.5 $\pm$ 0.3 and 29.5 $\pm$ 1.4 SE days in Alberta (Millar, 1985). Newborn deer mice are highly altricial (Layne, 1968).

Each year deer mice have approximately 2 litters, with the average for North America being 2.4 (Millar, 1989) and the average in alpine areas of Alberta, Canada, being 1.9 $\pm$ 0.1 SE (Millar and Innes, 1983). Litter size varies from 1 to 8 pups and mean liter sizes of 3.4 and 5.1 $\pm$ 0.14 SE have been reported in Virginia and Alberta, Canada (Millar, 1985; Wolff, 1985b). This compares to the average litter size in North America of 4.4 pups (Millar, 1989). First litters are consistently smaller than subsequent litters (Millar, 1989), and latitude and elevation explain a significant amount of the variation in litter size among *P. maniculatus* populations (Smith and McGinnis, 1968, as cited in Millar, 1989). Millar (1989) estimated the relationship between litter size and latitude and longitude to be:

$$Y = -1.62 + 0.0103X + 0.106Z + 0.0004X^2 - 0.0005Z^2$$

where, Y is the mean litter size; X is the latitude; and Z is the longitude.

Young are weaned within 16 to 25 days after birth with the average weaning time in North America being 20.2 days (Millar, 1989). In Alberta, young were weaned at 24.9 days (Millar and Innes, 1983) and in Colorado, weaning occurred at 17.5 days (Halfpenny, 1980).

Behavior and Social Organization

Deer mice are promiscuous; in one study, 19 to 43 percent of litters resulted from multiple inseminations (Birdsall and Nash, 1973, as cited in Millar, 1989).

3.2.22 Black-Tailed Jackrabbit (*Lepus californicus*)[2]

Black-tailed jackrabbits (also known as California jackrabbits) are in the order Lagomorpha, family Leporidae. Jackrabbits are technically hares, with their young born fully haired, unlike rabbits (Dunn et al., 1982). Three other species of jackrabbit occur in North America: the white-tailed jackrabbit (*L. townsendii*), the antelope jackrabbit (*L. alleni*), and the white-sided jackrabbit (*L. callotis*).

Distribution

The black-tailed jackrabbit is found in the western United States. It ranges from Missouri in the east to the Pacific coast, from the prairies of South Dakota to Texas, and from Washington and Idaho to Mexico in the south (Dunn et al., 1982). It has also been successfully introduced into several eastern states and may be displacing its eastern cousin, the white-tailed jackrabbit (Dunn et al., 1982).

Body Size and Weight

On average, *L. californicus* is smaller than *L. townsendii*. Total body lengths range from 465-630 mm, the tail is 50-112 mm, and the hind foot is from 112-145 mm (Dunn et al., 1982).

[2] Text directly from Sample et al. (1997a).

Representative body weights for black-tailed jackrabbits appear in Table 3-47. Newborn black-tailed jackrabbits have a total length of 168 mm, and weigh approximately 110 g (Dunn et al., 1982).

TABLE 3-47
Body Weights (kg) for the Black-Tailed Jackrabbit, *Lepus californicus*

Location	Sex	Mean	Range	Reference
Arkansas	Both	2.3	1.8-3.6	Silva and Downing, 1995
Colorado	Both	2.54		Dunn et al., 1982
California	Male	2.47	2.11-2.8	Lechleitner, 1959
	Female	2.78	2.3-3.3	
Utah	Male	2.03		Goodwin and Currie, 1965
	Female	2.17		

Food Habits and Diet Composition

Jackrabbits are strict herbivores, eating a variety of plants depending on availability and geographic location (Dunn et al., 1982). Black-tailed jackrabbits prefer succulent vegetation when available, with grasses and forbs being important in the summer and shrubs becoming more important in the winter (Dunn et al., 1982). Grasses and sedges may also be important food items. Additional information on foraging habits of black-tailed jackrabbits in different locations are presented in Westoby (1980), Currie and Goodwin (1966), Clark and Innis (1982), Gross et al. (1974), and Dunn et al. (1982).

Food Consumption Rate

Arthur and Gates (1988) estimated a forage intake rate of 145 g (dry weight)/d for black-tailed jackrabbits in Idaho. In Utah, Currie and Goodwin (1966) observed fall, winter, and spring food ingestion rates of 97.3 g (dry weight)/d, 111.4 g/d, and 61.3, g/d, respectively. Assuming a body weight of 2.1 kg (Goodwin and Currie, 1965) and a water content for dry grass of 10 percent (Table 3-4), daily food ingestion rates are equivalent to 0.076 g/g/d (Idaho), 0.051 g/g/d (fall, Utah), 0.059 g/g/d (winter, Utah), and 0.032 g/g/d (spring Utah).

Water Consumption Rate

Black-tailed jackrabbits are well-adapted to arid environments and are able to regulate water quite efficiently. They have the ability to elevate their body temperature during the day to avoid having to dissipate the heat and hence lose water (Hinds, 1977). Black-tailed jackrabbits also can concentrate urine to reduce water loss (Dunn et al., 1982). These factors suggest that black-tailed jackrabbits consume very little water and get most of their moisture from food.

Soil Ingestion

Arthur and Gates (1988) measured a mean (range) ingestion rate of soil for black-tailed jackrabbits in Idaho to be 9.7 (9.0-10.6) g/individual/d, with seasonal peaks occurring in spring and fall. This amount was equivalent to 6.3 percent of the total dry matter intake for black-tailed jackrabbits. Assuming a body weight of 2.54 kg (Dunn et al., 1982), soil ingestion is estimated to be 0.0038 g/g/d.

Respiration Rate

No literature data were found describing inhalation by black-tailed jackrabbits. Using Eq. 21 and assuming a body weight of 2.54 kg, the average inhalation rate is estimated to be 0.45 m^3/kg BW/d. If other body weight values are used, the inhalation rate should be recalculated.

Metabolism

At rest, the body temperature of adult jackrabbits is approximately 37° to 38°C (Dunn et al., 1982). Hinds (1977) discovered that body temperatures in laboratory jackrabbits do not differ significantly with season or on a diurnal basis. Hinds (1977) observed that the summer thermoneutral zone for black-tailed jackrabbits was 26° to 34°C, with an average basal metabolism of 0.562 ± 0.15 mL O_2/g/h. The winter thermoneutral zone was lower (21° to 28°C), and the average basal metabolism was 0.579 ± 0.004 mL O_2/g/h. Oxygen consumption at ambient temperatures both above and below thermoneutrality increased but at a quicker rate at lower temperatures.

In the summer, evaporative water loss averaged 0.135 ± 0.009 percent body mass/h, up to ambient temperatures of 26°C. At this temperature evaporative cooling commences, and water loss increases exponentially. In the winter, the entire range of physiological responses appears to be shifted to lower temperatures, so that water loss is higher in winter. Dry heat transfer and thermal conductance were also estimated by Hinds (1977). Both *L. californicus* and *L. alleni* survive in the desert by exploiting opportunities to minimize the heat load and water expenditure, but *L. alleni* seems to be better adapted to arid conditions. Strategies used by black-tailed jackrabbits to survive in the desert include increasing their body temperature during the day to store heat, concentrating their urine, excreting dry feces, and increasing blood flow to the ears to increase convective and radiative heat loss (Dunn et al., 1982).

Habitat Requirements

Although the black-tailed jackrabbit occupies many diverse habitats, it is primarily found in association with short grass areas in the arid regions of the western United States (Dunn et al., 1982). They inhabit desert shrub areas throughout their range but have also become well adapted to many agricultural situations in western states (Dunn et al., 1982).

Home Range

The home range size of the black-tailed jackrabbit is determined by the pattern of food, cover, and water in the surrounding area (Dunn et al., 1982). In California, Lechleitner (1958) reports that home ranges are usually less than 20.2 ha, with females having larger home ranges than males. In Idaho, home range sizes of less than 16.2 ha are reported (French et al., 1965).

Population Density

Population densities vary greatly by location. Density estimates for areas of the arid southwest range from 0.2/ha in Nevada (Hayden, 1966), to 0.9/ha in Utah, and to 1.2/ha in Arizona (Dunn et al., 1982). In more temperate regions, densities ranged from 3.0/ha in California (Leichleitner, 1958) to as high as 34.6/ha in agricultural areas in Kansas (Dunn et al., 1982). There also appear to be cycles in population densities, with peak densities occurring every 5 to 10 years, possibly because of density-dependent factors (French et al., 1965, Dunn et al., 1982).

Population Dynamics/Survival

Several extensive studies have been performed on the demographics of black-tailed jackrabbits (Lechleitner, 1959; Gross et al., 1974). There is evidence that populations are density dependent (French et al., 1965). Other researchers have also noted the tendency for population levels to cycle. In California, Lechleitner (1959) reported a preimplantation mortality of 6.7 percent and postimplantation mortality of 6.2 percent. In Utah, Gross et al. (1974) estimated preimplantation and postimplantation mortality rates of 8.0 and 3.0 percent, respectively. Juvenile mortality rates in Utah ranged from 24 to 71 percent (mean=59 percent; Gross et al., 1974), similar to juvenile mortality rates estimated for other locations (Dunn et al., 1982). Adult mortality rates were measured in Utah over an 8-year period, yielding mean yearly mortality rates of 56-57 percent with a range from 9 to 87 percent (Gross et al., 1974).

Reproduction/Breeding

Anatomically, male and female black-tailed jackrabbits are similar to domestic rabbits (Dunn et al., 1982). The length of their breeding season is highly variable, depending on latitude and various environmental factors. Generally, the breeding season is shorter for areas located at higher latitudes with more severe winters (French et al., 1965). This can be as short as 128 days in northern Idaho (French et al., 1965) to over 240 days in California with breeding possible all year round (Lechleitner, 1959). Gross et al. (1974) report the mean gestation period to be 40 days, ranging up to 47 days depending on the geographic location and the individual. The number of litters per year can also vary from two in colder climates to as many as seven in warmer climates, with the average annual production throughout the range being about 14 young per female (Dunn et al., 1982). The black-tailed jackrabbit is like other lagomorphs in that it is an induced ovulator with a relatively well-synchronized breeding season (Lechleitner, 1959; Gross et al., 1974). The litter size varies from about five in its northern range to two in its southern range (Dunn et al., 1982). Males will reach breeding age in seven to eight months, but females generally will not breed until their second year (Lechleitner, 1959; Bronson and Tiemeier, 1958).

Behavior

Black-tailed jackrabbits are crepuscular, generally feeding in the early morning and evening hours and overnight (Dunn et al., 1982). They prefer to eat in areas that are inconspicuous but that allow them to detect danger from a moderate distance. They often feed in the open, using hollows or open depressions (Dunn et al., 1982). Coprophagy, which is common in many lagomorphs, has also been observed in the black-tailed jackrabbit (Leichleitner, 1957).

3.2.23 Eastern Cottontail (*Sylvilagus floridanus*)[1]

The eastern cotton tail is in the order Lagomorpha, family Leporidae. Rabbits and hares are medium-sized grazing herbivores found throughout North America. Most species are nocturnal and crepuscular. Many are social, traveling in small groups. Rabbits are prey for large carnivorous birds and mammals.

Distribution

The eastern cottontail is the most widely distributed of the medium-sized rabbits (Chapman et al., 1982). It is found over most of the eastern half of the United States and southern Canada and has been widely introduced into the western United States (Chapman et al., 1980). North of Mexico, 14 subspecies are recognized (Chapman et al., 1982). The eastern cottontail feeds on green vegetation in summer and bark and twigs in winter. The cottontail is active from early evening to late morning and is preyed on by owls, hawks, and carnivorous mammals (Palmer and Fowler, 1975; Burt and Grossenheider, 1980).

Body Size and Weight

The eastern cottontail measures 35 to 43 cm in length and weighs 0.7 to 1.8 kg (Lord, 1963) with females slightly larger than the males (Nowak and Paradiso, 1983; see table). Cottontail body weight varies seasonally, increasing during spring and summer and declining during winter in some areas; different patterns occur in other areas (Chapman et al., 1982; Pelton and Jenkins, 1970). Body weights of eastern conttontails are detailed in Table 3-48.

Food Habits and Diet Composition

During the growing season, cottontails eat herbaceous plants (e. g., grasses, clover, timoth, alfalfa). During the winter in areas where herbaceous plants are not available, they consume woody vines, shrubs, and trees (e.g., birch, maple, apple) (Chapman et al., 1982). In Ohio, bluegrass and other grasses made up a large portion of the eastern cottontail's diet, except during snow cover (Chapman et al., 1982). During the winter in Connecticut, the principle diet of eastern and New England cottontails consists of bark and twigs, shrubs and vines, berries, and willow (Dalke and Sime, 1941). In agricultural areas, corn, soybeans, wheat, and other crops may comprise a large portion of their diet (Chapman et al., 1982). Younger rabbits prefer the more succulent weedy forbs that contain more digestible energy and protein (Chapman et al., 1982). Coprophagy (ingestion of feces) has been reported in *S. floridanus* (Kirkpatrick, 1956). The diet composition of eastern cottontails is detailed in Table 3-49.

Food Consumption Rate

No data on food consumption rates in eastern cottontails were available in the literature reviewed. Using Eq. 5 a food consumption rate of 0.07 kg/kgB W/day was calculated assuming a mean body weight of 1.22 kg (as calculated using the above table and adults). A fresh weight of 0.472 kg/kg BW/day was calculated assuming a diet of 64 percent grasses, 19 percent forbs, and 17 percent woody plants with respective water contents of 79, 85, and 9.3 percent (Table 3-4). (Note: Water content of woody plants assumed to be similar to that reported for seeds. If using different body weights, then the rate should be recalculated).

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[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

TABLE 3-48
Body Weights (g) of the Eastern Cottontail (*Sylvilagus floridanus*)

Location	Age/Sex	N	Mean	Range	Reference
w Maryland, West Virginia	Adult male		1,134 ± 122 SD	801-1,411	Chapman and Morgan, 1973
	Adult female				
Georgia	Adult (both):				Pelton and Jenkins, 1970
	winter		1,176	793 - 1,671	
	spring		1,286	898 - 1,630	
	summer		1,197	910 - 1,608	
	fall		1,255	886 - 1,669	
Georgia					Pelton and Jenkins, 1970
Mountain	Adult (both)		1,229 ± 113 SD	1,093 - 1,461	
Coastal	Adult (both)		1,313 ± 141 SD	986 - 1,671	
Piedmont	Adult (both)		1,132 ± 136 SD	793 - 1,579	
Illinois	Adult (both)		1,231 ± 164	700 - 1,800	Lord,1963
Alabama	neonate		42.2	36.0 - 49.0	Hill, 1972b
Illinois	age:				Lord,1963
	10 d		3.2		
	30 d		3.7		
	50 d		8.8		
	101 d		11.3		
	149 d		6.4		

Water Consumption Rate

Water consumption rates were not available in the literature reviewed. The estimated water consumption for adults of both sexes is 0.097 L/kg BW/day, using Eq. 19 and body weights from Lord (1963). (Note: If using different body weights, then the rate should be recalculated)

Soil Ingestion

No soil ingestion data for *S. floridanus* was available in the reviewed literature. However, Arthur and Gates (1988) reported a soil ingestion rate of 6.3 percent of the diet for black-tailed jackrabbits (*Lepus californicus*), and soil ingestion by *S. floridanus* is likely to be comparable.

TABLE 3-49
Diet Consumption of the Eastern Cottontail (*Sylvilagus floridanus*)

Location/Habitat	Dietary Composition	Spring	Summer	Fall	Winter	Reference
Connecticut/various	trees	13	2	7	39	Dalke and Sime, 1941
	shrubs and vines	4	2	27	40	(% frequency of occurrence; observations of feeding on plants)
	herbs	44	23	34	5	
	grasses, sedges and rushes	26	56	30	6	
	crops	13	17	2	10	
Maryland/forest	woody plants	17	23	20	100	Spencer and Chapman, 1986
	forbs	19	30	46		(% frequency of occurrence; stomach contents)
	grasses	64	47	34		
Ohio/NS	bluegrass	34	34	25	32.0	Dusi, 1952
	orchard grass	4	1	--	1	(% frequency of occurrence; scats)
	timothy grass	5	12	7	1	
	nodding wild rye	5	11	8	4	(in winter, woody tissue predominated in the unidentified category)
	Canada goldenrod	--	--	3	--	
	red clover	--	--	6	--	
	unidentified	52	42	51	62	

Respiration Rate

An inhalation rate of 0.52 m^3/kg BW/day was estimated using Eq. 21 and body weights from Lord (1963). (Note: If using different body weights, then the rate should be recalculated.)

Metabolism

The estimated basal metabolic rate for adults of both sexes is 71 kcal/kg BW/day using the equation in Boddington (1978) and body weights form Lord (1963). The estimated free-living metabolic rate is 203 kcal/kg BW/day (range 77-535) using the equation in Nagy (1987) and body weights from Lord (1963). (Note: If using different body weights, then the rate should be recalculated).

Eastern cottontails do not undergo hibernation or torpor; they are active all year, showing peaks of daily activity at dawn and dusk (Chapman et al., 1980). Adults molt gradually over about 9 months of the year, with two peak molting periods (Spinner, 1940). In Connecticut, the spring peak occurs in May and June and the fall peak occurs in September and October (Spinner, 1940). In Texas, spring and fall molts peak in April and October, respectively (Bothma and Teer, 1982).

Habitat Requirements

The eastern cottontail is unique to the genus because of the large variety of habitats that it occupies, including glades and woodlands, deserts, swamps, prairies, hardwood forests, rain forests, and boreal forests (Nowak and Paradiso, 1983). Open grassy areas generally are used for foraging at night, whereas dense, heavy cover typically is used for shelter during the day (Chapman et al., 1982). During winter, cottontails rely more on woody vegetation for adequate cover (Allen, 1984).

Home Range

Cottontails are found in a variety of habitats that contain weedy forbs and perennial grasses; they prefer thick, short, woody perennials that provide escape sites (Chapman and Ceballos, 1990). Cottontails usually do not defend territories; the home ranges of different age and sex groups tend to overlap, especially in fall and winter when they look for areas offering a combination of food and cover (Chapman et al., 1980, 1982). Home ranges are smaller when thick vegetation provides abundant food and larger in habitats with less food (Chapman et al., 1982). Home ranges also are smaller during severe winter weather than at other times (Chapman et al., 1982). The size of male home ranges during the breeding season can be more than double that in winter (Nowak and Paradiso, 1983; Trent and Rongstad, 1974).

Home ranges in Wisconsin were estimated by Dixon et al. (1981) and Trent and Rongstad (1974). Winter ranges were 3.05 ha for males and 2.99 ha for females. In the summer, ranges for females were 0.8 ha, while males had ranges of 4 ha in early summer and 1.5 ha in late summer. Home ranges in the spring for males and females were 2.8 and 1.7 ha, respectively. Althoff and Storm (1989) estimated ranges in Pennsylvania for adult females of 2.1 in the winter, 2.8 in the spring, 2.4 in the summer and 1.5 in the fall. Male ranges were 3.2 ha in the winter, 7.2 ha in the spring, 7.8 ha in the summer, and 3.1 ha in the fall.

Population Density

Population density depends on the availability of resources (e. g., food, cover) in an area, and tends to cycle over a period of several years (Chapman and Ceballos, 1990). Usual densities range from 1 to 5 animals per ha, although values as high as 14 per ha have been reported (Chapman and Ceballos, 1990; Chapman et al., 1982). Eberhardt et al (1963) reported fall densitis in woods, marshes, and fields of Michigan to be 1.1 $\pm$ 0.41 SD cottontails per ha. In Illinois, fall density was 3 to 59 cottontails per ha while winter density was 0.67 to 1.5 per ha (Lord and Casteel, 1960). A summer density of 4.2, a fall density of 10.1 and a spring density of 3.7 cottontails per ha were reported in Wisconsin farm areas (Trent and Tongstad, 1974).

Population Dynamics/Survival

The eastern cottontail exhibits the highest fecundity of the genus; they often produce 25 to 35 young per year (Chapman and Ceballos, 1990). Gestation lasts approximately 1 month (Chapman et al., 1982). Females may produce five to seven litters per year, and juvenile breeding has been reported (Chapman et al., 1982). Mean litter size ranges from 3.5 to 6 (Hill, 1972c; Lord, 1963; Conaway et al., 1963). The first and last litters of the year are usually the smallest (Chapman et al., 1977). Cottontails have more litters with fewer young each in the southern states (Lord, 1960). Young leave the nest when about age 14 to 16 d, although they may not be fully weaned until a few weeks later (Ecke, 1955). Female cottontails are capable of breeding by age 5 month, and males as early as 3 months (Bothma and Teer, 1977). Adult mortality is high, from approximately 65 to 75 percent per year in some places (Eberhardt et al., 1963). Juvenile mortality is even higher, between 85 and 90 percent in the same areas (Eberhardt et al., 1963). Mean longevity in Kentucky was reported as 1.25 years (Bruna, 1952).

Reproduction/Breeding

Breeding activity begins later at higher elevations and at higher latitudes (Conaway et al., 1974), by January in Alabama and by late March in southern Wisconsin (Chapman et al., 1980). Several studies have shown that continued harsh winter weather may delay the onset of the breeding season (Hamilton, 1940b; Conaway and Wight, 1962; Wight and Conaway, 1961). Breeding seasons are longer in the southern states (Lord, 1960). The onset of breeding varies between different populations and within the same population from year to year (Chapman et al., 1980). Males may fight to establish dominance hierarchies for access to females (Chapman and Ceballos, 1990; Nowak and Paradiso, 1983). Lagomorphs in general are induced ovulators, and cottontails in particular demonstrate a synchronized breeding season, with conception immediately after the birth of a litter (Chapman et al., 1982).

Chapman et al. (1977) reported a mean of 4.6 litters per year for cottontails breeding in western Maryland and later, a range of 5-7 litters per year across several locations and habitats (Chapman et al., 1980). Gestation lasts approximately 28 days (range 25-25 days; Chapman et al., 1982), and litter sizes vary widely as described previously. Hill (1972c) observed a mean litter size of 3.5 ± 0.042 young, which is less than mean litter sizes reported in Illinois (5.3 young/litter; Lord, 1963) and Missouri (6.0 young/litter; Conaway et al., 1963). Young are weaned between 20 to 25 days of age (Ecke, 1955).

Behavior and Social Organization

As indicated previously, eastern cottontails are active all year, showing peaks of daily activity at dawn and dusk (Chapman et al., 1980). During the breeding season, females build elaborate nests within slanting holes in the ground where they give birth to their altricial (helpless) young. These burrows are vulnerable to flooding (Chapman et al., 1982).

3.3 Birds

3.3.1 Great Blue Heron (*Ardea herodias*)[1]

The great blue heron is in the order Ciconiiformes, family Ardeidae. This bird is the largest member of the group in North America, and feeds primarily on aquatic animals. There are four subspecies in the United States and Canada (Bancroft, 1969, cited in Hancock and Kushlan, 1984), including an all white morph that was formerly considered a separate species (National Geographic Society, 1987).

Distribution

Great blue herons are widely distributed in both saltwater and freshwater environments, and range throughout the United States and Canada (Bancroft, 1969, cited in Hancock and Kushlan, 1984).

Body Size and Weight

Great blue herons are the largest heron in North America and are 106 to 132 cm tall. Males average slightly heavier in weight than females (Hartman, 1961; Palmer, 1962). Northern continental herons are somewhat smaller than those found in the south (Palmer, 1962). Quinney (1982) determined a relationship between age and body weight for nestling great blue herons (r = 0.996, N = 16 nestlings, and 274 measurements):

$$BW = 55.6\ (A-47.4)$$

where, BW equals body weight in grams and A equals age in days.

Body weights for great blue herons from different locations throughout their range are presented in Table 3-50.

TABLE 3-50
Body Weights (g) for the Great Blue Heron (*Ardea herodias*)

Location	Sex	Mean	Reference
Eastern North America	Both	2229±762[b]	Quinney, 1982
NS[c]			Hartman, 1961
	Male	2576±299[b]	
	Female	2204±337[b]	
Oregon			Bayer, 1981
	Both -Yearlings	2340±490[b]	
	Both -Juvenile	1990±550[b]	
Nova Scotia	Both- day 1	86	McAloney, 1973
	Both- day 5	170	
	Both- day 10	567	

[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

TABLE 3-50
Body Weights (g) for the Great Blue Heron (*Ardea herodias)*

Location	Sex	Mean	Reference
	Both- day 15	983	
	Both-day 20	1115	
	Both-day 25	1441	
	Both- day 30	1593	
	Both- day 35	1786	
	Both- day 40	2055	

[a] Not stated

Food Habits and Diet Composition

Fish are the preferred prey, but great blue herons also eat amphibians, reptiles, crustaceans, insects, birds, and mammals (Alexander, 1977; Bent, 1926; Hoffman, 1978; Kirkpatrick, 1940; Peifer, 1979). When fishing, they mainly use two foraging techniques: standing still and waiting for fish to swim within striking distance or slow wading to catch more sedentary prey (such as flounder and sculpin) (Bent, 1926; Willard, 1977). To fish, they require shallow waters (up to 0.5 m) with a firm substrate (Short and Cooper, 1985). Fish up to about 20 cm in length were dominant in the diet of herons foraging in southwestern Lake Erie (Hoffman, 1978), and 95 percent of fish consumed by great blues in a Wisconsin population were less than 25 cm in length (Kirkpatrick, 1940). Great blue herons sometimes forage in wet meadows and pastures in pursuit of lizards, small mammals, and large insects (Palmer, 1962; Peifer, 1979). In northern areas, small mammals such as meadow voles may be an important part of the diet early in the breeding season, possibly because some aquatic foraging areas may still be partially frozen when the herons arrive (Collazo, 1985). Food preferences of great blue herons are summarized in Table 3-51.

TABLE 3-51
Diet Composition of Great Blue Herons *(Ardeahendia)*

Location	Prey taxon	Percent volume	Reference
Lower Michigan/lake	Fish	98[a]	Alexander, 1977
	Trout	59	
	Non-trout	39	
	Crustaceans/Amphibians	2	
Lower Michigan/river	Fish	94 [a]	Alexander, 1977
	Trout	89	
	Non-trout	5	
	Crustaceans	1	
	Amphibians	4	

TABLE 3-51
Diet Composition of Great Blue Herons *(Ardeahendia)*

Location	Prey taxon	Percent volume	Reference
	Birds and Mammals	1	
Nova Scotia/Boot Island	Fish	100[b]	Quinney, 1982
	Atlantic silverside	3.6	
	Mummichog	2.4	
	American eel	52.6	
	Gaspereaux	29.9	
	Pollack	8.9	
	Yellow perch	2.6	
Vancouver/ coastal island	Fish	100[c]	Krebs, 1974
	Staghorn sculpin	37.6	
	Starry flounder	28.3	
	Other	34.1	

[a] Values are percent wet weight; stomach contents
[b] Values are percent wet weight; items regurgitated by nestlings
[c] Values are percent of fish observed caught

Food Consumption Rate

There are no studies available that give specific food consumption rates. However, Kushlan (1978) developed a regression equation relating the amount of food ingested per day to body weight for wading birds (N = seven species):

$$\log(FI) = 0.966 \log(BW) - 0.640$$

where, FI equals food ingestion in grams per day and BW equals body weight in grams.

The food ingestion rate based on this equation is 0.18 g/g BW/day, and is comparable to that obtained using Eq. 9 and a mean body weight of 2.28 kg (as calculated from values in the table above using adult birds). Food ingestion rate for the great blue heron is calculated to be 0.044 kg/kg BW/day. To convert this value into fresh weight, Eq. 18 was used and resulted in a value of 0.175 kg/kg BW/day FW. It was assumed that diet was 100 percent fish and mean water content was 75 percent as presented for bony fish in Table 3-4.

Water Consumption Rate

No literature data were found describing water ingestion by great blue herons. Using Eq. 20 and assuming a body weight of 2.28 kg, water ingestion is estimated to average 0.045 L/kg BW/day. (Note: if other body weights are used, then the water ingestion rate should be recalculated.)

Soil Ingestion

No information was found in the literature on soil ingestion. As a piscivorous, nonfossorial species, soil ingestion is likely to be negligible.

Respiration Rate

No literature data were located concerning inhalation rates for the great blue heron. An inhalation rate of 0.34 m^3air/kg BW/day or 0.77 m^3air/day can be estimated using Eq. 22 and a body weight of 2.28 kg ((Note: If different body weights are used, then the respiration rate should be recalculated.)

Metabolism

No literature-derived data concerning metabolism in great blue herons was available. The basal metabolic rate of 62 kcal/kg BW/day can be estimated using the equation in Lasiewski and Dawson (1967) and body weights from Quinney (1982). The free-living metabolic rate, 165 kcal/kg BW/day, was estimated using the equation in Nagy (1987) and body weights form Quinney (1982).

Habitat Requirements

Great blue herons inhabit a variety of freshwater and marine areas, including freshwater lakes and rivers, brackish marshes, lagoons, mangroves, and coastal wetlands, particularly where small fish are plentiful in shallow areas (Spendelow and Patton, 1988; Short and Cooper, 1985). They are often seen on tidal flats and sandbars and occasionally forage in wet meadows, pastures, and other terrestrial habitats (Palmer, 1962). Great blue herons tend to nest in dense colonies, or heronries. The location of the heronry is generally close to foraging grounds, and tall trees are preferred over shorter trees or bushes for nest sites (Bent, 1926; Palmer, 1962; Gibbs et al., 1987). They also may nest on the ground, on rock ledges, or on sea cliffs (Palmer, 1962).

Home Range

Bayer (1978) reported a mean (±SD) feeding territory of 0.6±0.1 ha for great blue herons feeding in freshwater marshes in Oregon. In contrast, great blue herons feeding in estuaries in Oregon had a mean (±SD) feeding territory of 8.4±5.4 ha. Breeding colonies are generally close to foraging grounds (Bent, 1926; Palmer, 1962; Gibbs et al., 1987). Mathisen and Richards (1978) found the distance between heronries and possible feeding areas in Minnesota lakes to range from 0 to 4.2 km, averaging 1.8 km. Another study found that most heronries along the North Carolina coast were located near inlets with large concentrations of fish, an average of 7 to 8 km away (Parnell and Soots, 1978, cited in Short and Cooper, 1985). Herons in South Dakota rivers and streams were observed to travel up to 24.4 km from the colony to forage, however, the mean distance was just 3.1 km (Dowd and Flake,, 1985). Fifteen to 20 km is the farthest great blue herons regularly travel between foraging areas and colonies (Gibbs et al., 1987; Gibbs, 1991; Peifer, 1979). Each breeding pair defends a small territory around the nest, the size of which depends on local habitat and the birds' stage of reproduction (Hancock and Kushlan, 1984). Herons in some areas also defend feeding territories (Peifer, 1979).

Population Density

Dowd and Flake (1985) reported great blue heron population densities of 2.3 birds/km along streams and 3.6 birds/km along rivers during the summer in North Dakota. On the coastal islands off Maine, summer nesting densities of great blue herons were 149±53 nests/ha (Gibbs et al., 1987) compared to 461 nests/ha (range 447-475 nests/ha) on a coastal island off Oregon (Werschkul et al., 1977). Because great blue herons nest colonially, local population density (i.e., colony density, colony size, and number of colonies) varies with the availability of suitable nesting habitat as well as foraging habitat. On islands in coastal Maine, Gibbs and others (1987) found a significant correlation between colony size and the area of tidal and intertidal wetlands within 20 km of the colonies, which was the longest distance herons in the study colonies traveled on foraging trips. In western Oregon, the size of heronries was found to range from 32 to 161 active nests; the area enclosed by peripheral nest trees within the colonies ranged from 0.08 to 1.21 ha (Werschkul et al., 1977).

Population Dynamics/Survival

Most nestling loss is a result of starvation, although some losses to predation do occur (Collazo, 1981: Hancock and Kushlan, 1984). In a study of 243 nests in a coastal California colony, 65 percent of the chicks fledged, 20 percent starved, 7 percent were taken by predators, and 7 percent were lost to other causes (Pratt and Winkler, 1985). Estimates of the number of young fledged each year by breeding pairs range from 0.85 to 3.1 (Pratt, 1970; Pratt, 1972; McAloney, 1973; Pratt and Winkler, 1985; Quinney, 1982). Based on banding studies, about two-thirds of the fledglings do not survive more than 1 year, although they may survive better in protected wildlife refuges (Bayer, 1981a). Values for later years indicate that about one-third to one-fifth of the 2-year-old and older birds are lost each year (Bayer, 1981a; Henny, 1972; Owen, 1959). Annual mortality rates reported by Henny (1972) for herons in the United States and Canada were 64 percent during the first year, 36 percent during the second year and 22 percent during the third year.

Reproduction/Breeding

The male great blue heron selects the site for the breeding territory, and nests generally consist of a stick platform over 1 m in diameter (Palmer, 1962). Great blues often use a nest for more than 1 year, expanding it with each use (Palmer, 1962). Timing of mating and egg laying varies with location and begins as early as November and lasts to April in Florida (Howell, 1932). In contrast, this period begins in mid-February, lasts until June, and peaks in mid-March in central California great blue heron populations (Pratt and Winkler, 1985). In northwest Oregon, mating and egg laying does not begin until mid-March (English, 1978). Timing is similar in Pennsylvania, with mating and egg laying season beginning in late-March and extending to early April (Miller, 1943). Farther north in Nova Scotia, breeding does not begin until mid-April and only lasts until late May with the peak period in early May (McAloney, 1973).

Mean clutch sizes range from 3 to 5 eggs; in general, clutch size tends to increase with latitude (Pratt, 1972). Mean clutch sizes for great blue herons nesting in California, Nova Scotia, and Pennsylvania were 3.16±0.04 SE, 4.17±0.85 SD, and 4.37, respectively (Pratt and Winkler, 1985; McAloney, 1973; and Miller, 1943). Incubation lasts approximately 25-30 days with mean incubation periods of 27.1 days in Nova Scotia (McAloney, 1973) and 28 days in the united States (Bent, 1926). Only one brood is raised per year; however, if a clutch is destroyed, great blues may lay a replacement clutch, usually with fewer eggs than the initial clutch (Palmer, 1962; Hancock and Kushlan, 1984). Two to 3 young per nest are successfully fledged with mean fledglings per successful nest of 2.19±0.25 SD, 2.43, and 3.09 in central California, northwest Oregon, and Nova Scotia (Pratt and Winkler, 1985; English, 1978; McAloney, 1973). Age at fledging can vary with mean ages of 45, 60, and 49-56 days reported (McAloney, 1973; Hancock and Kushlan, 1984; Quinney, 1982). The age of sexual maturity for male and female great blue herons is 2 years (Bent, 1926).

Behavior and Social Organization

In the northern part of its range, most great blue herons are migratory, some moving the southern Atlantic and Gulf States to overwinter with the resident population of herons (Bent, 1926; Palmer, 1962), others continuing on to Cuba and Central and South America (Hancock and Kushlan, 1984). Most migrating herons leave their breeding grounds by October or November and return between February and April (Bent, 1926). Fall migration usually occurs from in mid-September and ends in late October throughout the Northern United States (Palmer, 1962). Spring arrival usually begins in mid-February in Oregon and ends in mid-March (Werschkul et al., 1977). In Wisconsin, Minnesota and Nova Scotia spring arrival usually occurs in March (Bent, 1926). During the breeding season, great blues are monogamous and colonial, with from a few to hundreds of pairs nesting in the same area or heronry (Gibbs et al., 1987).

3.3.2 Green Heron (*Butorides virescens*)[2]

The green heron (also known as the green-backed heron) is in the order Ciconiformes, family Ardeidae. This small, compact wading bird is part of a world-wide complex of related species, considered by some to be a single species (Davis and Kushlan, 1994). This species is notable in that it has been observed to use a variety of baits and lures to catch prey.

Distribution

In eastern North America, the green heron occurs from the Atlantic Coast to the Great Plains, from southeastern Canada to the Gulf Coast and Florida (Davis and Kushlan, 1994). In the west, it is found along the Pacific Coast to Vancouver Island. Range of the green heron is limited by aridity, altitude, and high latitude (Davis and Kushlan, 1994).

Body Size and Weight

The green heron is small and stocky (41-46 cm long) with neck and legs shorter than those in other herons (Davis and Kushlan, 1994). Dunning (1993) reports the mean body weight of green herons from Florida to be 212±5.92 g (mean ±STD; n=34; sex not stated). In Louisiana, the mean body weight of 16 adults and 14 juveniles was 241 g and 219 g, respectively (Davis and Kushlan, 1994). Meyerriecks (1962) reports body weights for two males and a female to be 158 g, 191.6 g, and 181.5 g, respectively.

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[2] Text directly from Sample et al. (1997a).

Food Habits and Diet Composition

The diet of green herons consists primarily of fish (40 to >90 percent; Table 3-52). Other prey items include crayfish and other crustaceans, insects, spiders, and amphibians. Fish consumed are generally small in size. In Michigan, Alexander (1977) observed the following size distribution of fish consumed: 0 to 25.4 mm, 60 percent; 25 to 51 mm, 37 percent; 51 to 76 mm, 1.1 percent; and 76 to 100 mm, 2.2 percent. Prey consumed by herons in Louisiana ranged from 10 to 100 mm (Davis and Kushlan, 1994).

TABLE 3-52
Diet Composition of Green Herons *(Butorides virescens)*

Location	Prey Taxon	Percent Volume	Percent Frequency	Reference
Louisiana	Fish	93	93	Davis and Kushlan, 1994
(n=27)	Mosquitofish (*Gambusia affinis*)	1	11	
data from late summer	Shiners (*Notropis* spp.)	2	7	
	Sunfish (*Lepomis* spp.)	35	26	
	Pirate perch (*Aphredoderus sayanus*)	2	4	
	Threadfin shad (*Dorosoma petenense*)	53	48	
	Crustacea	1	22	
	Crayfish (Cambarinae)	1	11	
	Prawns (*Palaemonetes kadiakensis*)	<1	11	
	Insecta	6	63	
	Coleoptera	<1	4	
	Hemiptera	1	19	
	Odonata	2	48	
	Orthoptera	3	26	
	Arachnida	1	22	
	Water spiders (*Dolomedes* spp.)	1	22	
throughout United States	Noncommercial fishes	38.52		Meyerriecks, 1962
(N=255)	Food fishes	5.91		
	Undetermined fish fragments	0.96		
	Crustaceans	20.64		
	Insects	23.65		
	Spiders and other invertebrates	10.32		
Michigan	Fish	67		Alexander, 1977
(n=12)	Red belly dace	7.7[a]		
	Creek chub	3.3[a]		
	Darter	3.3[a]		

TABLE 3-52
Diet Composition of Green Herons *(Butorides virescens)*

Location	Prey Taxon	Percent Volume	Percent Frequency	Reference
	Brook stickleback	62.2[a]		
	Fathead minnow	13.3[a]		
	Mudminnow	7.7[a]		
	Largemouth bass	2.2[a]		
	Crustaceans	1		
	Insects	9		
	Amphibians	10		
	Vegetation	3		
	Unidentified	10		

[a] Values represent percent of total fish species consumed

Food Consumption Rate

Kushlan (1978) developed a model for estimation of daily food ingestion rates by herons

$$\log I_f = 0.966 (\log BW) - 0.64 ,$$

where

I_f = food ingestion rate (g fresh wt. /individual/d),

BW = body weight (g).

Assuming a body weight of 212 g (Dunning, 1993), green herons are estimated to consume 0.19 g/g/d. This estimate is comparable to that observed for two nestling green herons, just prior to fledging (16 percent of body mass/d; Junor, 1972). In contrast, Alexander (1977) estimates that green herons in Michigan consume 50 percent of their body mass in food per day. No data are presented to support this estimate, however.

Water Consumption Rate

No literature data were found describing water consumption by green herons. Using Eq. 20 and assuming a body weight of 212 g (Dunning, 1993), the average water ingestion rate is estimated to be 0.098 L/kg BW/d If other body weight values are used, the water consumption rate should be recalculated.

Soil Ingestion

Data concerning soil ingestion by green herons were not located in the literature. As a piscivorous, nonfossorial species, soil ingestion is likely to be negligible.

Respiration Rate

No literature data were found describing inhalation by green herons. Using Eq. 22 and assuming a body weight of 212 g (Dunning, 1993), the average inhalation rate is estimated to be 0.58 m^3/kg BW/d. If other body weight values are used, the inhalation rate should be recalculated.

Metabolism

No literature data on metabolism were located.

Habitat Requirements

Green herons are highly flexible, using almost any available fresh or salt water habitat within their range (Meyerriecks, 1962). Their primary requirement is dense vegetation. Green herons forage in swamps, marshes, riparian zones along creeks or human-made ditches, pond or lake edges, etc. (Davis and Kushlan, 1994). These herons generally avoid open flats frequented by other, longer-legged herons.

Home Range

Davis and Kushlan (1994) report that green herons defend feeding territories from conspecifics; however, specific data on home range and territory size in this species are lacking.

Population Density

Because green herons are generally solitary and widely dispersed, population density estimates are problematic (Davis and Kushlan, 1994).

Population Dynamics/Survival

There are few data on survivorship or longevity in green herons. Banding records indicate longevity of at least 7 years (Davis and Kushlan, 1994). Limited data on populations indicate somewhat increasing abundance in the eastern United States, with range expansions at its northern and western limits (Davis and Kushlan, 1994).

Reproduction/Breeding

Data on reproduction in green herons was derived from Bent (1926), Meyerriecks (1962), DeGraaf et al. (1981), and Davis and Kushlan (1994). Green herons may nest singly or in colonies. Nests are frequently in trees or shrubs near water, typically 3 to 4.5 m in height. In New York, eggs may be present from April 29 to August 4. Clutch sizes range from three to six eggs but are typically four to five eggs. Incubation lasts 19 to 21 days. Hatching success averages 78.9 percent. The nestling period lasts 16 to 17 days. Green herons produce one clutch/year in northern latitudes, two per year in the south. Green herons are sexually mature at one year of age but generally do not breed until their second year.

Behavior

Green herons use the fewest number of feeding behaviors reported for North American day herons (Davis and Kushlan, 1994). Of 36 potential behavior types, green herons used only 15. Green herons are also less active than other herons. Green herons are known to bait for fish using bread crusts, feathers, insects, worms, sticks, and plastic (Davis and Kushlan, 1994).

Green herons are migratory in the northern parts of their range (Meyerriecks, 1962). Migration generally occurs at night, either singly or as flocks of 50 or more individuals.

Social Organization

Green herons are not social outside the breeding season (Meyerriecks, 1962). They are typically solitary foragers. During the breeding season, they may nest singly or form small colonies of up to 30 pairs (DeGraaf et al, 1981). Green herons may also be found as part of mixed breeding colonies with other heron species (Davis and Kushlan, 1994).

3.3.3 Black-Crowned Night-Heron (*Nycticorax nycticorax*)[3]

Black-crowned night-herons are in the order Ciconiiformes, family Ardeidae. Night-herons are unique among herons as they are primarily nocturnal. They have stocky build with a comparatively short neck and legs.

Distribution

Black-crowned night-herons are cosmopolitan species, they are found on almost every continent with the exception of Australia and the Antarctic. There are four subspecies; *N. n nycticorax* occurs in Europe, Asia, and Africa and is slightly smaller than the North American *N. n. hoactli. N. N. hoactli* is common and widespread from Washington state, east to Quebec and New Brunswick, and south through coastal Mexico. *N. n. obscurus* is the largest of the subspecies and occurs in South America. *N. n. falklandicus* is similar to *hoactli,* but is limited to the Falkland Islands (Davis, 1993; Palmer, 1962).

Body Size and Weight

Black-crowned night-herons are medium sized herons with an average body length between 58 and 72 cm. Females are generally slightly smaller than males but measurements for the sexes may overlap.

TABLE 3-53
Body Weights (g) for the Black-Crowned Night-Heron (*Nycticorax nycticorax)*

Location	Sex	N	Mean	Minimum	Maximum	Reference
Massachusetts	Male	4	913	785	1014	Gross, 1923
	Female	4	827	727	862	

Food Habits and Diet Composition

Night-herons are opportunistic feeders. Although fish are their primary diet item, herons will also consume leeches, earthworms, aquatic and terrestrial insects, prawns, crayfish, mussels, squid, amphibians, reptiles, birds, rodents, eggs, carrion, plant material, and garbage or refuse from landfills (Davis, 1993). Food preferences of night herons from several locations are listed in Table 3-54

[3] New species accounts compiled for ARAMS.

TABLE 3-54
Diet Composition of the Black-Crowned Night-Heron (*Nycticorax nycticorax)*

Location	Food Items	Percent Occurrence	Reference
Richmond Co., New York	Estuarine		Parsons, 1990
	Fish	30	
	Invertebrates	5	
	Freshwater		
	Fish	8.8	
	Unknown Fish	12.5	
	Mammals	21.3	
	Human Refuse	5	
	Unknown	11.3	
	Other	6.3	
Florida	Fishes	59	Davis, 1993
	Crustaceans	21	
	Insects	16	
	Amphibians	7	
	Mammals	1.7	
Location	**Food Items**	**Percent Frequency Stomach Contents**	**Reference**
Southern Alberta	Fishes	29	Wolford and Boag, 1971
Marsh Habitat	Birds (young)	6	
	Mammals	12	
	Coleoptera	59	
	Hemiptera	41	
	Orthoptera	12	
	Odonata	12	
	Amphipoda	18	
	Vegetation	12	
Florida	Fishes	59	Davis, 1993
	Crustaceans	21	
	Insects	16	
	Amphibians	7	
	Mammals	1.7	

Food Consumption Rate

No data were available in the literature on food consumption rate of black-crowned night-herons. Using Eq. 9 and a mean body weight of 0.87 kg (as calculated from the above table using adult birds), a food consumption rate of 0.061 kg/kg BW/day can be estimated. A fresh weight of 0.27 kg/kg BW/day can be estimated assuming a diet of 59 percent fish, 37 percent invertebrates, 7 percent amphibians, and 1.7 percent mammals with respective water contents of 75, 76, 85, and 68 percent (Table 3-4). (Note: If using other body weight values, then the rates should be recalculated.)

Water Consumption Rate

No data were found in the literature regarding water consumption rate of black-crowned night-herons. Using Eq. 20 and a mean body weight of 0.87 kg, a rate of 0.062 L/kg BW/day was calculated. (Note: If using other body weight values, then the rate should be recalculated.)

Soil Ingestion Rate

No data were found in the literature regarding soil ingestion rate of black-crowned night-herons. Little ingestion of soil is expected from fish consumption, which makes up a large portion of the night-heron diet (>30 percent); however, ingestion of crustaceans such as crayfish is likely to result in consumption of sediment associated with these burrowing invertebrates. Therefore, it is recommended that the lowest soil ingestion rate (2 percent) reported in Beyer et al. (1994) be used for the black-crowned night-heron.

Respiration Rate

No data were found on respiration rate of black-crowned night-herons in the literature. Using Eq. 22 and a mean body weight of 0.87 kg, an inhalation rate of 0.42 m^3/kg BW/day can be estimated. (Note: If using other body weight values, then the rate should be recalculated.)

Metabolism

No information on metabolism of black-crowned night-herons could be found in the literature.

Habitat Requirements

Black-crowned night-herons are found in a variety of freshwater, brackish, and saltwater wetland habitats including marshes, swamps, streams, rivers, ponds, lakes, tidal mudflats, saltmarshes, and man made ditches, reservoirs, and wet agricultural fields. They prefer large wetlands with equal proportions of open water and vegetation (Hoefler, 1979).

Home Range

No specific data on the size of the home range for black-crowned night-herons was located in the literature. These herons are known to widely disperse after nesting. Most colonies are in the vicinity of large wetlands. During nesting, both the male and female will defend a territory around the nest that is approximately 8 ft wide and 4 ft high (Davis, 1993).

Population Density

The primary factors affecting population density are habitat alteration and availability of food. Storms and predation are the principle factors affecting nesting success. Due to their nocturnal behavior, these birds are inconspicuous and their numbers are frequently underestimated during surveys (Erwin, 1980; Portnoy, 1980).

Population Dynamics / Survival

Hicky (1952) reported adult mortality of 31 and 61 percent for first year birds and adults respectively. Birds have been reported to live 21 years (Houston, 1974) and the longevity record, based on federal bird band returns, is 21 years, one month (USGS Bird Banding Laboratory, May 2000).

Reproduction and Breeding

Black-crowned night-herons are monogamous. Males perform mating dances to attract a female, with nest building and copulation occurring shortly after the pair is formed. There are 3-5 eggs in a clutch and one brood is raised per year. Incubation lasts 23 to 26 days and is carried out by both adults (Hancock and Kushlan, 1984; Custer et al., 1992). Henry (1972) estimated that survival of two young per breeding season, which is approximately the average reported from the literature, would be sufficient to maintain a stable population. Young are able to leave the nest when disturbed at just 10 days of age, and were observed to eat on their own by 37 days of age in captive breeding birds (Davis, 1993).

Behavior

Black-crowned night-herons are social birds, with as many as twelve birds roosting together in a single tree, and they frequently associate with other herons. They will, however, aggressively defend feeding and nesting territories. Young herons will regurgitate and or defecate to discourage intruders. Night-herons, as the name implies, are nocturnal hunters, but during the breeding season they will feed during the daytime (Williams, 1979; Fasola, 1984).

Social Organization

There is no evidence for peck order or dominance in this species, however there is some evidence that older and more aggressive birds will defend larger territories (Lorenz, 1938).

3.3.4 Canada Goose (*Branta canadensis*)[1]

Canada geese belong to the order Anseriformes, family Anatidae. Geese are large herbivorous waterfowl that feed on grains, grass sprouts, and some aquatic vegetation. Although adapted for life on the water, they forage primarily in open fields. They breed in open forested areas near lake shores and coastal marshes from the arctic tundra through temperate climates. These birds migrate in noisy flocks in the familiar V-formation, stopping in cultivated fields, wetlands, and grasslands to feed. Geese show a wide variation in size even within a species; the sexes look alike.

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[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

Distribution

The Canada goose is the most widespread and abundant goose in North America. It is a popular game species and is commonly encountered on cultivated fields, golf courses, other parklands, and wetland refuge areas. Depending on the subspecies, these geese can range in size from 64 to 114 cm (bill tip to tail tip). The number of subspecies recognized has varied, but most ornithologists agree on at least 11: *canadensis* ("Atlantic"), *fulva* ("Vancouver"), *interior* ("Interior"), *maxima* ("Giant"), *moffitti* ("Great Basin" or "Western"), *occidentalis* ("Dusky"), *parvipes* ("Lesser"), *hutchinsii* ("Richardson's"), *taverneri* ("Taverner's"), *minima* ("Cackling") and *leucopareia* ("Aleutian") (Bellrose, 1976; Johnson et al., 1979; Palmer, 1962). Recent genetic evidence indicates the small-bodied subspecies (*hutchinsii, taverneri, minima, and leucopareia*) are closely related and form an evolutionarily distinct lineage unique from the large-bodied subspecies (*canadensis, fulva, interior, maxima, moffitti, occidentalis, and parvipes*). The ornithological community regards this distinction as being significant enough to merit specific status and has officially recognized this split by reclassifying the small-bodied subspecies under the newly designated species name, Cackling goose (*Branta hutchinsii*)(Banks et al., 2004). Both species occupy relatively distinct breeding ranges but species and subspecies are usually found mixed together during migration and in wintering areas. Generally, the larger subspecies winter further north than smaller subspecies but this pattern is reversed on the breeding grounds where smaller birds tend to summer further north than their larger relatives (Palmer, 1962). Accordingly, the smaller Cackling goose has the more northernly range of the two species, breeding narrowly from Baffin Island and Queen Maud Gulf west through central Yukon to the Aleutian Islands and northern Alaska. The larger Canada Goose breeds from central Alaska east to northern Quebec and south to south-central Wyoming and northern Virginia. See Bellrose (1976) for ranges, migration corridors, and wintering areas of specific subspecies and populations.

Body Size and Weight

Canada geese subspecies vary greatly in size, but males are on average larger than females. Body weight reaches its maximum just prior to or during the spring migration and then declines during egg-laying and incubation, sometimes by as much as 20 percent (Mainguy and Thomas, 1985; McLandress and Raveling, 1981). Most of the weight lost during incubation reflects loss of fat, which can provide over 80 percent of the energy requirements for the incubating females (Mainguy and Thomas, 1985; Murphy and Boag, 1989). Young are similar to parents in size by 2 months of age (Palmer, 1962). Body weights for Canada geese from different locations throughout their range are presented in Table 3-55.

TABLE 3-55.
Body Weights (g) for the Canada Goose (*Branta canadensis)*

Location	Sex	Mean	Reference
Alaska	Male	1443±32	Raveling, 1979
	Female	1362±54	
Colorado	Male	2769±30	Grieb, 1970
	Female	2472±23	
NS[a]	Male	3992	Webster (unpublished) in Bellrose, 1976

TABLE 3-55.
Body Weights (g) for the Canada Goose (*Branta canadensis)*

Location	Sex	Mean	Reference
	Female	3447	
Illinois	Male	4212±35	Raveling, 1968
	Female	3550±31	
Missouri	Male	4960	Brakhage, 1965
	Female	4160	
Alberta	Male-hatching	108.7	LeBlanc, 1987b
	Female-hatching	109.5	
Alaska	Both – day 10	150	Sedinger, 1986
	Both – day 20	450	
	Both – day 30	755	
	Both – day 40	950	
	Both – day 47	1050	
NS	Both – day 0	110	Wiliams (unpublished) in Palmer, 1976
	Both – day 9	240	
	Both – day 16	440	
	Both – day 30	1400	
	Both – day 44	2400	
	Both – day 51	2600	
Alaska	Male–fledging	87 percent of adult	Sedinger, 1986
	Female-fledging	89 percent of adult	

[a] Not stated

Food Habits and Diet Composition

Canada geese are almost exclusively vegetarian, and feeding activity is concentrated in areas where food is plentiful (e. g., standing crops, scattered whole grain) (Palmer, 1962). They are primarily grazers, but must consume grit at some point to assure proper digestion (Palmer, 1962). They prefer certain foods, but will change their diet depending on the availability of a food type (Coleman and Boag, 1987). For example, when water levels are low in the south Yukon (Canada) river delta, Canada geese forage on rhizomes of *Potamogeton richardsonii* even though other forage is available; at higher water levels when the *Potamogeton* is unreachable, the geese will feed on other plants (Coleman and Boag, 1987). During fall, geese often consume green crops (e. g., winter wheat). During winter, however, they consume more energy-rich foods such as corn (Harvey et al., 1988; McLandress and Raveling, 1981). In late winter and early spring, green crops that are high in nitrogen and other important nutrients again constitute an important part of the diet (McLandress and Raveling, 1981). Canada geese often feed preferentially on the blade tips of many plants, which are higher in nitrogen than other parts of the plant (Buchsbaum et al., 1981). In Minnesota, Canada geese begin consuming green grasses as soon as they are exposed by the melting snow (McLandress and Raveling, 1981). In Maryland, on the other hand, Harvey et al. (1988) found that Canada geese did not begin consuming green crops before migration to the breeding grounds, indicating that this population may rely on green forage available at staging areas to obtain the protein and lipids required for reproduction. In the spring in Falmouth Harbor, Massachusetts, Canada geese initially consume predominantly the marsh grasses *Spartina* spp. and rushes *Juncus gerardi*, which are high in protein (Buchsbaum and Valiela, 1987). As the summer progresses, however, they feed increasingly on submerged eelgrass, *Zostera marina*, which provides more carbohydrates (Buchsbaum and Valiela, 1987). Food preferences of Canada geese are summarized in Table 3-56.

TABLE 3-56
Diet Composition of Canada Geese (*Branta canadensis)*

Location	Prey Taxon	Percent Volume	Reference
North Carolina-lake	Sedges	63[a]	Yelverton and Quay, 1959
	Native grasses	11	
	Corn kernels	22	
	Animal	0.01	
	Other	4	
Ontario, Canada -bay	*Equisetum* spp. - shoot	9.2[b]	Prevett et al., 1985
	Triglochin palustris - root	3.4	
	Grasses	25.5	
	Root	23.4	
	Shoot	2.1	
	Sedges	48.5	
	Root	25.3	
	Shoot	5.3	
	Reed	17.9	
	Plantago maritima -root	6.5	
	Unidentified plants	6.1	
	Invertebrates	0.7	
Wisconsin -marsh	Corn	23[c]	Craven and Hunt, 1984
	Unidentified plants	8.6	
	Alfalfa	10.4	
	Gramineae	12.6	
	Oats	25.1	
	Setaria lutescens	8.4	
	Trifolium repens	10.9	

[a]Crop and gizzard contents
[b]Percent dry weight; esophagus and proventriculus contents
[c]Percent dry volume; gizzard and proventriculus contents

Food Consumption Rate

Joyner et al. (1984) measured the winter and spring food ingestion rates for adult male and female captive Canada geese. In winter, males had a food ingestion rate of 0.030 g/g/day and females had a rate of 0.033 g/g/day. Rates were similar in spring, with males and females having a food ingestion rate of 0.030 and 0.031, respectively. These rates were reported as grams dry weight of feed, and were corrected to grams wet weight of feed using the measured moisture content of 11 percent (on average) of the feed items (i.e., corn, sunflower seeds, wheat, and milo). If estimated using Eq. 9 and a mean body weight of 3.11 kg (as calculated from above table using adult birds) the consumption rate is 0.039 kg/kg BW/day DW. Using Eq. 18 a fresh weight rate was estimated assuming a diet of 63 percent sedges, 11 percent grasses, and 22 percent corn kernel (Yelverton and Clay, 1959). Water content for grasses had a range from 70 to 88 percent (Table 3-4). The midpoint (79) of this range was used for both sedges and grasses. Corn kernels were considered seeds, which had a water content of 9.3 percent (Table 3-4). The estimated fresh weight food consumption rate was 0.098 kg/kg BW/day FW.

Water Consumption Rate

No literature data were found describing water ingestion by Canada geese. Using Eq. 20 and assuming a body weight of 3.11 kg, water ingestion is estimated to average 0.041 L/kg BW/day (Note: if other body weight values are used, then the water ingestion rate should be recalculated.)

Soil Ingestion

Soil ingestion was estimated to be 8.2 percent of diet for the Canada goose (Beyer et al., 1994). This would result in a rate of 0.002 kg/kg BW/day using a food consumption rate of 0.03 kg/kg BW/day.

Respiration Rate

No data concerning respiration in Canada geese were located in the literature. Using Eq. 22 and a body weight of 3.11 kg, an inhalation rate of 0.32 m^3 air/kg BW/day can be estimated. (Note: If other body weight values are used, then the inhalation rate should be recalculated.)

Metabolism

Free-living metabolic rates were found to be 105 to 209 kcal/kg BW/day in the winter for males, 105 to 203 in the spring for males, 115 to 253 in summer for males, 100 to 209 in the fall for males, 130 to 220 in the spring for females, and 143 to 274 in the summer for females (Williams and Kendeigh, 1982). Values were also estimated for males (185 kcal/kg BW/day) and females (187 kcal/kg BW/day) using the equation in Nagy (1987) and body weights from Raveling (1979). When body weights from Raveling (1968) were used, values were 141 and 147 kcal/kg BW/day, respectively. Body weights from Brakhage (1965) resulted in estimates of 135 and 142 kcal/kg BW/d.

Habitat Requirements

Breeding habitat includes tundra, forest muskeg in the far north, tall-and shortgrass prairie, marshes, ponds, and lakes. Most nesting sites are close to open water with high visibility in all directions (Palmer, 1962; Steel et al., 1957). In many areas, Canada geese nest predominantly on islands in ponds or lakes (Geis, 1956). Former muskrat houses often serve as nest sites in marshes (Steel et al., 1957). Brood-rearing habitats, on the other hand, require adequate cover, and riparian areas are used more frequently than open water (Eberhardt et al., 1989a). During the fall and winter in Maryland, Harvey et al. (1988) found Canada geese to spend 57 percent of their time in farmlands (mostly corn, soybeans, and winter wheat fields) and 24 percent in forested areas.

Home Range

The foraging home range of Canada geese varies with season, latitude, and breeding condition. Soon after hatching, goose families move away from the nesting sites to other areas with adequate cover and forage to rear their broods (Byrd and Woolington, 1983). Newly hatched families may have to travel 10 to 20 km from the nest site to reach areas with adequate aquatic vegetation or pasture grasses (Geis, 1956). Although the families stay predominantly on land, often in riparian areas, they usually are close to water. Eberhardt et al. (1989a) found goslings within 5 m of water most of the time; only 7 percent of sightings were farther than 50 m away. During the spring and fall migrations and in winter, Canada geese can be found on open water or refuges near grain fields or coastal estuaries (Leopold et al., 1981). Females with their broods in riverine habitats of Washington had home ranges of 983±822 ha (range, 290 – 2830 ha) or 8.8±4.4 km (range, 2.8 – 18.1 km) (Eberhardt et al., 1989a).

Population Density

Breeding population densities of Canada geese vary widely. Low nesting densities (i. e., less than 0.005 per ha) are common in the Northwest Territories of Canada (Smith and Sutton, 1953, 1954) and intermediate densities (i. e., 0.02 to 0.7 per ha) have been reported for Alaska (Cornley et al., 1985). In some more southerly locations (e. g., California), colonial nesting situations have been reported, with as many as 32 nests located on half an acre (Naylor, 1953, as cited in Palmer, 1962). In various locations, summer breeding densities ranged from 0.02 to 12.4 nests/ha (Cooper 1978). In Montana, breeding densities were 16.6 nests/ha on a 0.2-0.8 ha island and 1.3 nests/ha on a 8-121 ha island (Geis, 1956). In contrast, breeding densities in Alaska were only 0.35 nests/ha (Byrd and Woolington, 1983). Humburg et al. (1985) measured population densities of Canada geese at a wildlife refuge in Missouri, and reported 22 birds/ha in the fall and 4 birds/ha in the winter.

Population Dynamics/Survival

The earliest Canada geese begin breeding is around 2 to 3 years of age (MacInnes and Dunn, 1988; Brakhage, 1965). In the larger subspecies, only a small proportion of the birds under 4 years may attempt to breed. For example, in Manitoba, Moser and Rusch (1989) found that only 7 percent of 2-year-old and 15 percent of 3-year-old *B. c. interior* laid eggs. Canada geese only attempt to rear one brood per year. In the more southerly latitudes, Canada geese will renest if a clutch is lost prior to incubation (Brakhage, 1965; Geis, 1956). In general, both clutch size and success at rearing goslings increase with the age of the breeder (Brakhage, 1965). Raveling (1981) found that older *B. c. maxima* (4 plus years) raised more than twice as many goslings to fledging as did younger (2 to 3 years) birds. Population age structure and annual mortality vary with hunting pressure as well as natural factors. In Alaska, annual mortality for adults was 35.9 percent and for juveniles was 46 percent (Nelson and Hansen, 1959). In California and Nevada, Rienecker (1987) found average mortality rates to be 28±0.8 SD percent for adults and 49±3.7 percent for juveniles.

Cummings (1973) reported an annual mortality rate of 22.9 percent for adults in Ohio and 37 percent for juveniles.

Reproduction/Breeding

Canada geese arrive on the breeding grounds in flocks, and soon after, the male becomes territorial and aggressive toward other birds (Palmer, 1962). Lifelong monogamy following their first breeding is the general rule with these geese (Palmer, 1962). Nests are built on the ground in a position with good visibility (Palmer, 1962). As with many other species, the timing of mating and egg-laying varies with latitude. Geese in Georgia and Alabama begin in late February and end in mid-May with the peak in March-April (Combs et al., 1984), while this period begins in early March in Oregon, Washington, and California with the peak in late March (McCabe, 1979; Bellrose, 1976). Montana geese begin mating and egg laying in mid-March and end in May with a peak from late March to April (Geis, 1956). Mating and egg laying periods in Idaho and Ontario are similar with both starting in early April and ending in early May and mid-April in Idaho and Ontario, respectively (Steel et al., 1957; Mainguy and Thomas, 1985). Finally, geese in Alaska begin mating in late May and end egg laying in early June (Byrd and Woolington, 1983).

During incubation the male stands guard, while the female incubates the eggs, which she normally leaves two or three times daily to feed, bath, drink, and preen (Murphy and Boag, 1989). Incubation periods of 25 and 28 days have been reported (Laidley, 1939; Brakhage, 1965). Only one clutch is laid per year (Brakhage, 1985), although Canada geese nesting in southern latitudes have been observed to renest if the clutch is lost prior to incubation (Brakhage, 1965; Geis, 1956). Clutch size ranges from 4 to 6 eggs with mean clutch sizes of 4.7, 5.6±0.1 SE, 4.6, and 5.6 reported (Spencer et al, 1951; Byrd and Woolington, 1983; Raveling and Lumsden, 1977; Combs et al,. 1984). Reported age at fledging differed among locations. Chicks were fledged at 40-46 days in Alaska (Mickelson, 1973), 63 days in Ontario (Hanson, 1965), and 71-73 days in Michigan (Sherwood, 1965). Nest success varies and was reported in Alaska as 91 percent (Byrd and Woolington, 1983) compared to only 44 percent in Alabama and Georgia (Combs et al., 1984). Estimates of 2 to 4 Canada geese fledge per successful nest with mean values of 4.0±0.008 SE, 2.2, and 3.9 $\underline{+}$ 1.9 SD reported (Byrd and Woolington, 1983; Hardy and Tacha, 1989; Everhardt et al, 1989b). Number chicks fledged per active nest was 2.19±2.42 SD (range, 0-7) in Washington (Eberhardt et al., 1989b). Both parents accompany the young through the brood period (Bellrose, 1976; Brakhage, 1965). Canada geese return to the breeding grounds as family units, but the yearlings leave their parents soon after arrival (Bellrose, 1976).

Behavior and Social Organization

Migratory Canada geese leave their breeding grounds during late summer and early autumn; they return in the spring around the time the first water is opening (i. e., ice melting) but well before snow cover has disappeared (Bellrose, 1976). Spring migration begins later for northerly populations, with geese that winter in mild climates departing as early as mid-January, while those wintering in the coldest areas do not move northward until the beginning of March (Bellrose, 1976). The bulk of the migrants typically arrive on the summer breeding grounds 3 weeks after the first birds (Bellrose, 1976). Some populations have become resident year-round, for example, *B. c. maxima* in Missouri (Brakhage, 1965) and in southeast Georgia and southwest Alabama (Combs et al., 1984).

During both the spring and fall migrations, geese tend to gather in large flocks and feed for several weeks in "staging" areas along major waterfowl flyways (Bellrose, 1976).

Fall migration into south Illinois peaks in November (Bell and Klimstra, 1970) with migration into Colorado and Texas peaking in early November and ending in mid-December (Grieb, 1970). Spring migration from Illinois begins in February and peaks in early March (Bell and Klimstra, 1970) while spring migration from Minnesota peaks in early April (Raveling, 1978b).

3.3.5 Mallard (*Anas platyrhynchos*)[1]

The Mallard belong to the order Anseriformes, family Anatidae. Surface-feeding ducks are the most familiar ducks of freshwater and saltwater wetlands. They feed by dabbling and tipping up in shallow water, often filtering through soft mud for food. They feed primarily on seeds of aquatic plants and cultivated grains, although they also consume aquatic invertebrates, particularly during the breeding season (Jorde et al., 1983; Swanson et al., 1985). All species have a bright colored patch of feathers on the trailing edge of each wing, and the overall plumage of the males is more colorful than that of the females. Dabbling ducks range in size from the green-winged teal (average 37 cm bill tip to tail tip) to the northern pintail (average 66 cm). The mallard feeds mostly on aquatic plants, seeds, and aquatic invertebrates, depending on the season, and forages in ponds and wetlands by dabbling and filtering through sediments.

Distribution

The mallard is widespread throughout most of the United States and is the most abundant of the United States ducks (USFWS, 1991). In the past decade, however, its numbers have declined markedly across its principal range in the mid-continental region because of habitat degradation and drought (USFWS, 1991). Mallards interbreed with domestic ducks and black ducks (*Anas rubripes*). Although the mallard winters in all four waterfowl flyways of North America (i. e., Pacific, Central, Mississippi, and Atlantic), the Mississippi flyway (alluvial valley from Missouri to the Gulf of Mexico) contains the highest numbers (Bellrose, 1976). Human creation and alteration of water bodies and plant communities have changed the migration and wintering patterns of mallards; in North America the ducks winter farther north than in the past (Jorde et al., 1983).

Body Size and Weight

Mallards average 58 cm from bill tip to tail tip. Male mallards are generally heavier than females (Delnicki and Reinecke, 1986; Whyte and Bolen, 1984; see table). Female mallards lose weight during the laying and incubation periods; males lose weight from their spring arrival through the peak of the breeding season and then gain weight while the females are incubating (Lokemoen et al., 1990a). Body weights for Mallard ducks from different locations throughout their range are presented in Table 3-57.

[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

TABLE 3-57
Body Weights (g) for the Mallard Duck (*Anas platyrhynchos)*

Location	Sex	Mean	Reference
Throughout North America	Male	1225	Nelson & Martin, 1953
	Female	1043	
Western Mississippi	Male	1246±108	Delnicki & Reinecke, 1986
	Female	1095±106	
Texas	Male	1237±118	Whyte & Bolen, 1984
	Female	1088±105	
North Dakota	Female	1197±105	Krapu & Doty, 1979
North Dakota	Egg	32.2 –66.7	Eldridge & Krapu, 1988
Central North Dakota	At hatching	32.4±2.4	Lokemoen et al., 1990a
Central North Dakota	Both at 3.5 days	32.4±2.4	Lokemoen et al., 1990b
Central North Dakota	Female at 9.5 days	115±37	Lokemoen et al., 1990b
	Female at 15.5 days	265±92	
	Female at 30.5 days	401±92	
	Female fleding at 56.0 days	740±115	
Central North Dakota	Male at 9.5 days	92±12	Lokemoen et al., 1990b
	Male at 15.5 days	215±5	
	Male at 30.5 days	460±93	
	Male fleding at 56.0 days	817±91	

Food Habits and Diet Composition

In winter, mallards feed primarily on seeds but also on invertebrates associated with leaf litter and wetlands, mast, agricultural grains, and to a limited extent, leaves, buds, stems, rootlets, and tubers (Goodman and Fisher, 1962; Heitmeyer, 1985, cited in Allen, 1987). In spring, females shift from a largely herbivorous diet to a diet of mainly invertebrates to obtain protein for their prebasic molt and then for egg production (Swanson and Meyer, 1973; Swanson et al., 1979; Swanson et al., 1985; Heitmeyer, 1988b). Laying females consume a higher proportion of animal foods on the breeding grounds than do males or nonlaying females (Swanson et al., 1985). The animal diet continues throughout the summer, as many females lay clutches to replace destroyed nests (Swanson et al., 1979;

Swanson et al., 1985). Ducklings also consume aquatic invertebrates almost exclusively, particularly during the period of rapid growth (Chura, 1961). Mallards concentrate in wetlands at night, apparently feeding on emerging insects (Swanson and Meyer, 1973). Flocks may feed in unharvested grain fields and stubble fields during fall and winter (Dillon, 1959). During periods of food shortage, fat reserves are used as an energy source. During breeding, females continue to feed but also use fat to meet the demands of egg production; females may lose 25 percent of their body mass (in fat) during laying and early incubation (Krapu, 1981). Food preferences of Mallard ducks are summarized in Table 3-58.

TABLE 3-58
Diet Composition of Mallard Ducks (*Anas platyrhynchos)*

Location	Prey Taxon	Percent Volume	Reference
Louisiana-coastal march and prairie	Rice	24[a]	Dillon, 1959
	Jungle Rice	21	
	Brownseed Paspalum	19	
	Barnyard Grass	8.0	
	Red rice	8.0	
	Knot Grass	6.5	
	Signal Grass	2.5	
	Coast Cockspur	1.9	
	Mamaica Sawgrass	1.3	
	Snails	1.0	
	Other	6.8	
South Central North Dakota-Prairie Potholes			
April	Total Animal	67.8[b]	Swanson et al., 1985
	Gastropods	Trace	
	Insects	13.1	
	Crustacea	7.9	
	Annelids	38.3	
	Misc. animal	8.5	
	Total Plant	32.2	
	Seeds	28.7	
	Tubers	2.4	
	Stems	1.1	
May	Total Animal	66.8	

TABLE 3-58
Diet Composition of Mallard Ducks (*Anas platyrhynchos)*

Location	Prey Taxon	Percent Volume	Reference
	Gastropods	24.9	
	Insects	25.6	
	Crustacea	15.1	
	Annelids	0.2	
	Misc. animal	1.0	
	Total Plant	33.2	
	Seeds	28.7	
	Tubers	4.3	
	Stems	0.2	
June	Total Animal	89.4	
	Gastropods	16.5	
	Insects	48.1	
	Crustacea	13.9	
	Annelids	10.9	
	Misc. animal	-	
	Total Plant	10.6	
	Seeds	10.6	
	Tubers	-	
	Stems	-	

[a] percent volume; gullet contents.
[b] percent wet volume; esophagus contents.

Food Consumption Rate

No literature was found on food consumption rate. Values were estimated (0.056 kg/kg BW/day DW) using Eq. 9 and assuming a mean body weight of 1.12 kg (as calculated from the above table using adult birds). To calculate a fresh weight value (0.79 kg/kg BW/day) the diet was assumed to be 13.9 percent aquatic invertebrates, 75.5 percent terrestrial invertebrates, and 10.6 percent seeds as presented in the table above (Swanson et al., 1985). The crab was used to determine water content of aquatic invertebrates (74 percent), the beetle was deemed representative of terrestrial invertebrates (61 percent) and seeds were reported as having a water content of 9.3 percent (Table 3-4).

Water Consumption Rate

No literature was found on water consumption rates for the mallard. However, a water consumption rate of 0.057 L/kg BW/day can be estimated using Eq. 20 and a mean body weight of 1.12 kg. (Note: If other body weights values are used, then the water consumption rate should be recalculated.)

Soil Ingestion

Percent soil ingestion in diets of the mallard were presented in Beyer et al (1994) as 3.3 percent of the diet. This percent would result in an estimate of 0.002 kg/kg BW/day FW.

Respiration Rate

No literature data were located concerning inhalation rates for mallards. Using Eq. 22 and a mean body weight of 1.12 kg, an inhalation rate of 0.45 m^3 air/kg BW/day can be estimated. (Note: If other body weights values are used, then the inhalation rate should be recalculated.)

Metabolism

Metabolic rate in the winter was found to be 280 and 220 kcal/kg BW/day for females and males, respectively (Whyte and Bolen, 1984). Basal metabolic rate can be estimated using the equation in Lasiewski and Dawson (1967). Males had a mean rate of 77 kcal/kg BW/day while females had a mean rate of 73. Free-living metabolic rate was found to be 200 and 192 kcal/kg BW/day for males and females, respectively, using the equation in Nagy (1987). Both free living and basil metabolic rate estimations used body weights from Nelson and Martin (1953).

Habitat Requirements

Wintering mallards prefer natural bottomland wetlands and rivers to reservoirs and farm ponds (Heitmeyer and Vohs, 1984); water depths of 20 to 40 cm are optimum for foraging (Heitmeyer, 1985, cited in Allen, 1987). The primary habitat requirement for nesting appears to be dense grassy vegetation at least a half meter high (Bellrose, 1976). Mallards prefer areas that provide concealment from predators such as seeded cover (fields established on former croplands) (Klett et al., 1988; Lokemoen et al., 1990b), cool-season introduced legumes and grasses (Duebbert and Lokemoen, 1976), and idle grassland with tall, dense, rank cover in the area (Duebbert and Kantrud, 1974). Nests usually are located within a few kilometers of water, but if choice nesting habitat is not available nearby, females may nest further away (Bellrose, 1976; Duebbert and Lokemoen, 1976).

Home Range

Each pair of mallards uses a home range, and the drake commonly establishes a territory that he defends against other mallards (Bellrose, 1976). Home-range size depends on habitat, in particular the type and distribution of water habitats (e. g., prairie potholes, rivers), and population density (Bellrose, 1976; Dwyer et al., 1979b; Kirby et al., 1985). Females in prairie potholes regions of North Dakota had a mean home range of 468±159 SD ha (range, 307-719 ha), and egg laying females had a mean home range of 111±76 SD ha (range, 38-240 ha; Dwyer et al., 1979b). In wetlands and rivers of Minnesota, Kirby et al. (1985) reported home ranges of 540 ha (range, 40-1440 ha) and 620 ha (range, 70-1410 ha) for females and males, respectively.

Population Density

Mallard densities during the breeding season are positively correlated with availability of terrestrial cover for nesting and with availability of wetlands and ponds that provide the aquatic diet of mallards (Pospahala et al., 1974). Availability of suitable wetland habitat for breeding and wintering depends on environmental conditions (e. g., rainfall) (Heitmeyer and Vohs, 1984; Lokemoen et al., 1990a). Average densities of breeding mallards in the prairie pothole region range from 0.006 to 0.87 pairs/ha (Duebbert and Kantrud, 1974; Duebbert and Lokemoen, 1976; Kantrud and Stewart, 1977; Lokemoen et al., 1990b). Mean densities in two different pothole areas were 0.036 and 0.047 pairs/ha, respectively. Mallards attain their highest densities in prairie and parkland of the southern prairie provinces and in the Cooper River and Athabasca River deltas of Canada (Johnson and Grier, 1988).

Population Dynamics/Survival

Nest success or failure is an important factor affecting mallard populations. Mammalian predation is the main cause of nest failure, followed by human disturbance (e. g., farming operations) and adverse weather conditions (Klett et al., 1988; Lokemoen et al., 1988). Mammalian predators include fox, badger, and skunk; crows also prey on mallard nests (Johnson et al., 1988). Mallards usually renest if the first nest fails (Palmer, 1976). Juvenile survival depends on food and preferred habitat availability, factors that in turn are affected by environmental conditions. For example, high rainfall is related to increased wetland area, which is positively correlated with duckling growth (Lokemoen et al., 1990a). Annual adult mortality rates vary with year, location, hunting pressure, age, and sex. Females suffer greater natural mortality rates (e. g., typical values of 40 to 50 percent) than do males (e. g., typical values of 30 to 40 percent) (Chu and Hestbeck, 1989). By fall, there is a higher proportion of males than females in most populations (Bellrose, 1976). Immature mortality rates of 70 percent have been recorded in many areas, although lower immature mortality rates are more common (Bellrose, 1976; Chu and Hestbeck, 1989). Annual mortality rates also are greater in areas with higher hunting pressure (Bellrose, 1976).

Bellrose (1976) reported mortality rates of 27.2 percent for adult males and 38.2 percent for adult females in the eastern-central flyway. Adult fall mortality in the western mid-Atlantic from 1971 to 1985 was 40.1±3.1 SE (range, 22-51 percent) and 49.9±3.3 SE percent (range, 20-72 percent) in males and females, respectively (Chu and Hestbeck, 1989). Juveniles of the same area suffered 41.1±7.2 SE percent (range, 31-59 percent) mortality in males and 48.8 ± 6.0 SE percent (range, 15-68 percent) mortality in females. In contrast, mallards in the northeastern United States studied by the same authors from 1971 to 1985 suffered mean (± SE) fall mortality rates of 39.9±2.3 (range, 9-10 percent) and 51.5±1.9 percent (range, 33-64 percent) for males and females, respectively. Mean rates (± SE) were 48.1±5.3 percent (range, 7-69 percent) for juvenile males and 56.8±3.2 percent (range, 38-68 percent) for juvenile females.

Reproduction/Breeding

Older females arrive at breeding grounds earlier than yearling birds, which probably increases their chances of reproductive success because they can select the best nest sites (Lokemoen et al., 1990b). First clutches are generally finished by mid-April in the southern part of the breeding range and late April to May in the northern United States

(Palmer, 1976). High rates of nest failure require females to renest persistently to reproduce successfully (Swanson et al., 1985).

Average clutch size decreases as the season progresses because the clutch size of renesting females is smaller than initial clutches (Eldridge and Krapu, 1988; Lokemoen et al., 1990b). Older females produce larger clutches than do yearlings (Lokemoen et al., 1990a). Clutch size varies from 1 to 18 eggs (mean, 9 eggs; Bellrose, 1976), with mean sizes of 9.3±1.7 SE in yearlings and 10.3±1.1 SE in adults that nested in the prairie pothole region of North Dakota (Krapu and Doty, 1979). In an experimental pond where nests were purposely destroyed, up to 4.5 nesting attempts were made (Swanson et al., 1985). If successful, only one clutch per year is produced (Bellrose, 1976).

Incubation lasts 23 to 29 days with mean reported periods of 26 days (Bent, 1923) and 25 days (Klett and Johnson, 1982). Chicks fledge between 52 and 60 days post-hatch (Bellrose, 1976) with a reported mean of 56 days from the prairie pothole region (Lokemoen et al., 1990a). Nest success varies greatly with a nest success of 51 to 61 percent in prairie potholes and fields in South Dakota (Duebbert and Lokemoen, 1976) and 9 to 10 percent in potholes in eastern South Dakota (Klett et al., 1988).

Behavior and Social Organization

Mallards mate for one breeding season, and males typically leave the females at the onset of incubation (Palmer, 1976). Females remain with the brood until fledging. Mallards are serially monogamous and thus re-mate annually (Palmer, 1976). Mallards tend to arrive at their wintering grounds in the Mississippi Valley in mid-September through early November and depart for their northerly breeding grounds again in March (Fredrickson and Heitmeyer, 1988). Adult females that reproduce successfully are likely to return to the same nesting ground the following year (Lokemoen et al., 1990a, 1990b). Spring migration has been noted to begin in mid-March and end in mid-May (Johnson et al., 1987) with fall migration peaking in November (Palmer, 1976).

3.3.6 Lesser Scaup (*Aythya affinis*)[1]

Lesser scaup (*Aythya affinis*) belong to the order Anseriformes, family Anatidae and are often referred to as bay ducks. Bay ducks are adapted for diving and characteristically need a running start to become airborne because their legs are located further back on their body than on other ducks. They breed at mid to high latitudes and winter in flocks on large water bodies and in protected coastal bays and river mouths. Bay ducks dive for their food, and their diet is omnivorous (i. e., both plant and animal matter) and depends on the seasonal and regional abundance of food resources. Because of their food habits, bay ducks prefer deeper, more permanent ponds than dabbling ducks (Bellrose, 1976). The sexes vary in coloration, and different bay duck species range in length from 42 to 53 cm (bill tip to tail tip).

Distribution

The lesser scaup is one of the most abundant North American ducks (Allen, 1986a). They breed principally throughout western Canada and Alaska, although their breeding range

[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

extends into the western United States as far south as Colorado and Ohio. Lesser scaup winter in the United States in the Mississippi flyway and the Atlantic flyway (Bellrose, 1976). They also winter along all coastal areas in the southern states and into Mexico (National Geographic Society, 1987). The axis of the main migration corridor extends from the breeding grounds on the Yukon Flats, Alaska, to wintering areas in Florida (Bellrose, 1976).

Body Size and Weight

The lesser scaup averages 42 cm from bill tip to tail tip. Males are larger and more colorful than the brown females (Bellrose, 1976). Following their post-breeding molt, scaups increase their fat reserves in preparation for migration (Austin and Fredrickson, 1987). Body weights for Lesser Scaups from different locations throughout their range are presented in Table 3 59.

TABLE 3-59
Body Weights (g) for the Lesser Scaup (*Aythya affinis)*

Location	Sex	Mean	Reference
Manitoba, Canada	Female-preflightless	688	Austin & Fredrickson, 1987
	Female-Flightless	647	
	Female-Postflightless	693	
	Female-Migratory	842	
United States	Female	770	Nelson & Martin, 1953
	Male	860	

Food Habits and Diet Composition

Most populations of lesser scaup consume primarily aquatic invertebrates, both from the water column and from the surfaces of aquatic vegetation and other substrates (Tome and Wrubleski, 1988; Bartonek and Hickey, 1969). Common prey include snails, clams, scuds (amphipods), midges, chironomids, and leeches. Scaup are omnivorous, however, and the percentage of plant materials (almost exclusively seeds) in the diet varies seasonally as the availability of different foods changes (Afton et al., 1991; Dirschl, 1969; Rogers and Korschgen, 1966). When seeds are locally abundant, they may be consumed in large quantities (Dirschl, 1969). Breeding females and ducklings eat mostly aquatic invertebrates (Sugden, 1973). Young ducklings feed primarily on water-column invertebrates (e. g., phantom midges, clam shrimps, water mites), whereas older ducklings forage mainly on bottom-dwelling invertebrates (e. g., scuds or amphipods, dragonflies, caddisflies) (Bartonek and Murdy, 1970). During the winter, there are no significant differences in diet between juveniles and adults or between males and females (Afton et al., 1991). Food preferences of Lesser Scaups are summarized in Table 3-60.

TABLE 3-60
Diet Composition of Lesser Scaups (*Aythya affinis)*

Location	Prey Taxon	Percent Volume	Reference
Louisiana-Lakes, marshes	Animal	60.9[a]	Afton et al., 1991
	Midges	45.9	
	Snails	7.7	
	Grass Shrimp	7.3	
	Plant-Seeds	36.1	
	Bulrush	36.0	
	Plant-Vegetative	3.0	
	Green Algae	2.3	
Northwest Territories-Lakes			Bartonek & Murdy, 1970
Summer	Animal	100[b]	
	Scuds	1±1	
	Phantom midges	54±8	
	Clam shrimps	30±8	
	Dragon/Damselfies	-	
	Water bugs	4±3	
	Water Mites	8±3	
	Caddis Flies	-	
	Water Beetles	1±1	
	Mayflies	2±1	
	Plants	Trace	
Fall	Animal	100	
	Scuds	57±9	
	Phantom midges	1±1	
	Clam shrimps	2±2	
	Dragon/Damselfies	17±8	
	Water bugs	11±7	
	Water Mites	-	
	Caddis Flies	6±5	
	Water Beetles	4±3	
	Mayflies	-	
	Plants	Trace	
NW Minnesota-lakes, marshes, pools			Afton et al., 1991
Spring	Animal	91.8[a]	
	Scuds (amphipods)	33.2	
	Dragonflies	-	

TABLE 3-60
Diet Composition of Lesser Scaups (*Aythya affinis)*

Location	Prey Taxon	Percent Volume	Reference
	Caddis Flies	8.8	
	Midges	2.3	
	Other Insects	4.9	
	Snails	31.9	
	Fingernail Clams	6.0	
	Brook Stickleback	-	
	Fathead Minnow	-	
	Other Fish	3.5	
	Plants – Seeds	6.0	
	Plants - Vegetative	2.2	
Fall	Animal	90.5	
	Scuds (amphipods)	54.9	
	Dragonflies	2.4	
	Caddis Flies	7.6	
	Midges	-	
	Other Insects	-	
	Snails	10.2	
	Fingernail Clams	5.1	
	Brook Stickleback	4.1	
	Fathead Minnow	5.0	
	Other Fish		
	Plants – Seeds	9.4	
	Plants - Vegetative	0.1	
Saskatchewan, Canada-Shallow Lakes			Dirschl, 1969
Spring	Animal	90.9[c]	
	Scuds	66.0	
	Diptera	-	
	Leeches	12.0	
	Fingernail Clams	12.7	
	Cyprinid Fish	-	
	Caddis Flies	0.2	
	Clam Shrimps	-	
	Plant – Seeds	9.1	
	Nuphar Variegatum	-	
	Other Seeds	9.1	

TABLE 3-60
Diet Composition of Lesser Scaups (*Aythya affinis)*

Location	Prey Taxon	Percent Volume	Reference
Summer	Animal	75.1	
	Scuds	9.8	
	Diptera	1.3	
	Leeches	23.7	
	Fingernail Clams	25.7	
	Cyprinid Fish	2.9	
	Caddis Flies	1.6	
	Clam Shrimps	3.1	
	Plant – Seeds	24.9	
	Nuphar Variegatum	13.2	
	Other Seeds	11.7	
Fall	Animal	49.6	
	Scuds	42.5	
	Diptera	0.1	
	Leeches	1.6	
	Fingernail Clams	-	
	Cyprinid Fish	-	
	Caddis Flies	1.9	
	Clam Shrimps	0.5	
	Plant – Seeds	50.4	
	Nuphar Variegatum	42.8	
	Other Seeds	7.6	

[a] percent dry weight: esophageal & proventricular contents
[b] percent wet volume $\pm$ SE; esophageal contents
[c] percent dry weight: esophagus and proventriculus contents

Food Consumption Rate

Juvenile lesser scaup between 1 and 5 weeks of age consumed 0.162 g/g BW/day in dry matter intake per wet body weight in a outdoor pens in Saskatchewan (Sudgen and Harris, 1972). The same study also found food consumption rates of 0.077 g/g BW/day in dry matter intake per wet body weight for juveniles 6-12 weeks old. Using Eq. 9 and a mean body weight of 0.75 kg (as calculated from the above table using adult birds) an estimated food consumption rate of 0.064 kg/kg BW/day can be calculated. Fresh weight was determined using Eq. 18 and assuming a summer diet of 12.7 percent terrestrial invertebrates, 3.1 percent clam shrimps, 2.9 percent cyrinid fish, 25.7 fingernail clams, 23.7 percent leaches, 7 percent other aquatic invertebrates, and 24.9 percent seeds (Dirschl, 1969). Water content was assumed to be 61 percent for the terrestrial invertebrates as was presented for the beetle, 78 percent for the shrimp, 28 percent for the cyrinid fish as presented for the herring, 82 percent for the clams as presented for bivalves, and 78 percent for leaches and other aquatic organisms as presented for shrimp (Table 3-4). The fresh weight estimate was 0.42 kg/kg BW/day.

Water Consumption Rate

No literature was found which presented water ingestion rates. Using Eq. 20 and a mean body weight of 0.75 kg, an estimate of 0.065 L/kg BW/day was calculated. (Note: If using different body weights, then the water ingestion rate should be recalculated.)

Soil Ingestion

No information was found on soil ingestion for the lesser scaup. Mallards and lesser scaups have a similar diet, therefore the soil ingestion rate of 3.3 percent of the diet reported for mallards in Beyer et al (1994) is likely to be representative of that expected for scaups. Using this percent, an ingestion rate of 0.002 kg/kg BW/day can be estimated.

Respiration Rate

No data on inhalation rates in lesser scaup were identified in the literature reviewed. An estimate of 0.44 m^3air/kg BW/day can be calculated using Eq. 22 and a mean body weight of 0.75 kg. (Note: If using different body weights, then the rate should be recalculated.)

Metabolism

Resting metabolic rate at 20 to 30 °C was found to be 90 kcal/kg BW/day for lesser scaup(McEwan and Koelink, 1973). Basal metabolism, 81 and 83 kcal/kg BW/day, was estimated for males and females, respectively using the equation in Lasieski and Dawson (1967). Free-living metabolic rate was also calculated for males (211 kcal/kg-day) and females (216 kcal/kg-day) using the equation in Nagy (1987). Body weights from Nelson and Martin (1953) were used for both basal and free-living metabolic rate estimates.

Habitat Requirements

Lesser scaup are found on large lakes and bays during the fall and winter and are common on smaller bodies of water (e. g., ponds) during the spring. They breed in the prairie potholes region, most often on permanent or semipermanent wetlands of 0.85 to 2.0 ha with trees and shrubs bordering at least half of the shorelines (Bellrose, 1976; Smith, 1971, cited in Allen, 1986b). Primary brood habitat is characterized by permanent wetlands dominated by emergent vegetation (Smith, 1971, cited in Allen, 1986b). In a study of ducks wintering in South Carolina, Bergan and Smith (1989) found lesser scaup would forage primarily in areas with submergent vegetation but also in areas of emergent vegetation, shallow open water, and floating-leaved vegetation. They found some differences in foraging habitat use by season and between males and females. In particular, females tended to use more shallow habitats than males, and males preferred open water in late fall (Bergan and Smith, 1989).

Home Range

Relatively small nesting territories and large highly overlapping foraging ranges are characteristic of lesser scaup (Hammel, 1973, cited in Allen, 1986b). Several pairs can nest in close proximity without aggression, each defending only a small area immediately surrounding the nest (Bellrose, 1976; Vermeer, 1970). In Manitoba, Hammel (1973) reported the mean (± SE) minimum foraging home range for lesser scaup to be 89 ± 6. 5 ha. Initial areas occupied by pairs usually contain stumps, logs, boulders, or beaches as loafing sites, but later lesser scaup rely solely on open water (Gehrman, 1951, cited in Bellrose, 1976).

Population Density

In winter, local densities of scaup can be very high, as large flocks float on favored feeding areas (Bellrose, 1976). In summer, the density of breeding pairs increases with the permanence and size of the ponds (Kantrud and Stewart, 1977). Kantrud and Stewart (1977) reported a population density in North Dakota of 0.029 pairs/ha in a seasonal wetland and 0.061 pairs/ha in a permanent wetland. In Alberta, on islands within lakes a mean of 28.9 pairs/ha (range, 13.1-58.5) were noted (Vermeer, 1970).

Population Dynamics/Survival

In some populations, many yearling and some 2-year-olds do not breed; the proportion breeding tends to increase with improving water and habitat conditions (Afton, 1984; McKnight and Buss, 1962). In a 4-year study in Manitoba, Afton (1984) found that, on average, 30 percent of 1-year-olds and 10 percent of 2-year-olds, did not breed. Clutch size and reproductive performance of adult females generally increase with age (Afton, 1984). Most nest failures are due to predation (e. g., by mink, raccoons, red fox), and scaup often attempt to renest if the initial nest fails (Afton, 1984; Bellrose, 1976). Annual mortality for juveniles (68-71 percent) is higher than that for adults, and adult female mortality (49-60 percent) exceeds adult male mortality (38-52 percent; Smith, 1963).

Reproduction/Breeding

Scaup build nests on the ground among tall grasses, shrubs, or forbs where plant heights range from 20 to 60 cm (Hines, 1977). Nests can be located along the edge of shorelines to upland areas (Bellrose, 1976). Courtship and pair bonds start to form on the wintering grounds, and pairs typically remain together for only one season. One clutch per year is laid, although renesting often occurs of the first clutch is lost (Afton, 1984). Clutch size ranges from 9 to 12 eggs. Second year females in Manitoba had mean (± SE) clutch sizes of 10.0 ± 0.2 eggs (range, 8-12) compared to larger clutches (12.1 ± 0.2 SE eggs; range, 11-14) in fourth year adults (Afton, 1984). In Saskatchewan on a marsh island, females laid 9.47 ± 0.12 (range, 7-12 eggs per clutch (Hines, 1977).

Males do not remain long after incubation commences (Trauger, 1971, cited in Bellrose, 1976). Incubation lasts 21 to 27 days with a reported mean of 24.8 days (Vermeer, 1968). Hatching success varies by age of female. Mean rates of 26.3, 22.2, and 45.5 percent were reported for first year, second year, and third year females, respectively, nesting in Manitoba lakes (Afton, 1984). A much greater percentage (76 percent) of nests hatched in Saskatchewan (Hines, 1977). The female and her brood leave the vicinity of the nest shortly after the ducklings have hatched. Most broods are on their own by 4 to 5 weeks of age (Gehrman, 1951, cited in Bellrose, 1976) and fledge between 7 and 9 weeks of age (mean, 65 ± 0.91 SE days; Lightbody and Ankney, 1984). Afton (1984) observed 67.5 ± 4.9 SE percent of broods surviving up to 20 days of age in Manitoba.

Behavior and Social Organization

Females of this species often lay eggs in other lesser scaup nests (nest parasitism), which can result in large compound clutches of lesser scaup eggs in a single nest (Hines, 1977). Hines (1977) also found that mixing of broods was common in Saskatchewan; by August, groups of 15 to 40 ducklings led by two to three hens would be common. Female lesser scaup also occasionally lay eggs in the nests of other ducks (e. g., gadwall; Hines, 1977).

Most scaup winter in the United States, with the greatest numbers in the Mississippi flyway and the Atlantic flyway. They start to arrive at their wintering areas in mid-October (Bellrose, 1976). The timing of northward migration in the spring varies from February to May (Bellrose, 1976). Before migration, scaup gain weight by increasing their body fat content (Austin and Fredrickson, 1987). Spring migration peaks from March to April and ends in May along the northern border of the United States, south of Manitoba while fall migration peaks in mid-November and ends in December (Bellrose, 1976).

3.3.7 Osprey (Pandion haliaetus)[1]

Osprey belong to the order Falconiformes, family Accipitridae. The only North American member of the subfamily Pandioninae, these large birds of prey have long narrow wings, a sharp hooked bill, and powerful talons. Osprey are found near freshwater or saltwater, and their diet is almost completely restricted to fish. They are adapted for hovering over the water and dive feet-first, seizing fish with their talons (Robbins et al., 1983).

Distribution

Once very rare owing to DDT accumulation in their food (1950's to early 1970's), osprey now are increasing in numbers. In the United States, there are five regional populations of osprey (in order of abundance): Atlantic coast, Florida and gulf coast, Pacific Northwest, western interior, and Great Lakes (Henny, 1983). In North America, osprey breed primarily in a wide band from coast to coast across Canada and the southern half of Alaska, where they are not restricted to coastal and Great Lake areas as they are in the United States. However, osprey are reported from all States during the fall and spring migrations (Henny, 1986).

Body Size and Weight

The various subspecies of osprey around the world differ in size, and in general females are heavier than males (Poole, 1989a; see table). Osprey found in the United States are considered to be of the subspecies *carolinenesis* and average 56 cm from bill tip to tail tip (Robbins et al., 1983) and weigh between 1.2 and 1.9 kg. Body weights for osprey from different locations throughout their range are presented in Table 3-61.

[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

TABLE 3-61
Body Weights (g) for the Osprey (*Pandion haliaetus)*

Location	Sex	Mean	Reference
NS[a]	Female	1568	Brown & Amadon, 1968
	Male	1403	
Massachusetts	Female-Courtship	1880±20	Poole, 1984
	Female-Incubation	1925±25	
	Female-Late Nestl.	1725±25	
	Male Courtship	1480±15	
	Male Late Nestl.	1420±15	
Mayland, Virginia	Female at Fledging	1510	McLean, 1986
	Male at Fledging	1210	

[a]Not Stated.

Food Habits and Diet Composition

Osprey are almost completely piscivorous, although they have been observed on occasion taking other prey including birds, frogs, and crustaceans (Brown and Amadon, 1968). Their prey preferences change seasonally with the abundance of the local fish (Edwards, 1988; Greene et al., 1983). Osprey occasionally will pick up dead fish but only if fresh (Bent, 1937). Osprey are most successful catching species of slow-moving fish that eat benthic organisms in shallow waters and fish that remain near the water's surface (Poole, 1989a). Osprey consume all parts of a fish except the larger bones; later, bones and other undigestible parts are ejected in fecal pellets (Bent, 1937). Food preferences of osprey are summarized in Table 3-62.

TABLE 3-62
Diet Composition of Osprey (*Pandion haliaetus)*

Location	Prey Taxon	Percent Volume	Reference
Nova Scotia, Canada-Harbor, Bay	Alewife	32[a]	Greene et al., 1983
	Smelt	5	
	Pollock	53	
	Winter Flounder	10	
Alaska	Starry Flounder	95[b]	Hughes, 1983
	Cutthroat Trout	5	
Oregon	Carp	67[b]	Hughes, 1983
	Crappie	33	

TABLE 3-62
Diet Composition of Osprey (*Pandion haliaetus)*

Location	Prey Taxon	Percent Volume	Reference
Florida-Lake	Gizzard Shad	63[c]	Collopy, 1984
	Sunfish	29	
	Largemouth Bass	5	
	Golden Shiner	3	
Idaho-Reservoir	Brown Bullhead	37.7[d]	Van Daele & Van Daele, 1982
	Salmonids	20.8	
	Northern Squawfish	19.3	
	Yellow Perch	11.6	
	Largescale Sucker	10.6	

[a] percent wet weight; observed captures
[b] percent wet weight; observed captures, noting fish length
[c] percent of prey caught; identified at nests
[d] percent of fish caught; observed captures

Food Consumption Rate

During courtship adult females in southeast Massachusetts consumed 0.21 g/g BW/day (Poole, 1983). Using Eq. 9 and a mean body weight of 1.63 kg (as calculated from the above table using adult birds), a food ingestion rate of 0.049 kg/kg BW/day DW can be estimated. Equation 18 can be used to determine fresh weight (0.196 kg/kg BW/day). The diet was assumed to be 100 percent fish with a water content of 75 percent (Table 3-4). (Note: if using different body weights, then the rate should be recalculated.)

Water Consumption Rate

No literature data were found describing water ingestion by osprey. Using Eq. 20 and a mean body weight of 1.63 kg, a water consumption rate of 0.05 L/kg BW/day was estimated. (Note: If using different body weights, then the water consumption rate should be recalculated.)

Soil Ingestion

No literature data were located concerning soil ingestion in osprey. As a piscivorous, nonfossorial species, soil ingestion is likely to be negligible.

Respiration Rate

No literature data were located concerning inhalation rates for osprey. Using Eq. 22 and a mean body weight of 1.63 kg, an inhalation rate of 0.37 m^3 air/kg BW/day. (Note: If using different body weights, then the rate should be recalculated.)

Metabolism

No literature values were found for metabolic rate. Estimates for basal metabolic rate were 69 and 71 kcal/kg BW/day for females and males, respectively using the equation from Lasiewski and Dawson (1967) and body weights from Brown and Amadon (1968). Free-living metabolic rates for males and females, 181 and 186 kcal/kg BW/day, were estimated using the equation in Nagy (1987) and body weights from Brown and Amadon (1968).

Habitat Requirements

In the United States, the majority of osprey populations are associated with marine environments, but large inland rivers, lakes, and reservoirs also may support osprey (Henny, 1986, 1988b). Good nesting sites in proximity to open, shallow water and a plentiful supply of fish are the primary resources required for osprey success (Poole, 1989a). The tops of isolated and often dead trees and man-made structures are preferred nesting sites. Osprey often nest in colonies (Poole, 1989a).

Home Range

The distance osprey travel from their nests to forage (i. e., foraging radius) depends on the availability of appropriate nest sites near areas with sufficient fish; osprey will travel up to 10 to 15 km to obtain food (Van Daele and Van Daele, 1982). Dunstan (1973) reported a foraging radius of 1.7 km (range, 0.7-2.7 km) for adult male osprey in lakes of Minnesota. While, Greene et al. (1983) reported a mean foraging radius of 10 km on the coastline of Novia Scotia during spring. Ospreys had mean foraging radii of 3 to 8 km in the coastal areas of northern California (Koplin, 1981).

Population Density

Population density depends on the availability and distribution of resources and can be highly variable. Henny (1988a) reported as many as 1.9 nests/ha in one of the largest osprey colonies in the western United States in 1899, with an estimated 1.0 to 1.2 nests/ha occupied that year. Lower densities on the order of 0.005 to 0.1 nests/ha are more common (Henny and Noltemeier, 1975). Eichholz (1980) reported a density of 0.028 nests/ha during the spring in Florida wetlands.

Population Dynamics/Survival

Breeding data from many locations in the United States and Canada during the years 1950 to 1976 show low productivity (fewer than one chick fledged per active nest on average). Evidence indicates the cause to be egg-shell thinning that resulted from the ospreys' exposure to DDT that had bioaccumulated in fish (Henny and Anthony, 1989; Henny et al., 1977; Poole, 1989a). Thus, data from reproductive studies conducted during this time can only be used with this in mind (Spitzer et al., 1978). Because of their terminal position in the aquatic food chain, osprey can be a sensitive indicator of toxic contaminants that bioaccumulate (Henny et al., 1978; Henny, 1988b).

Osprey are only known to start a second clutch if the first one is destroyed (Poole, 1989a). Juveniles do not return to their place of birth until 2 years of age, and they do not breed until their third season (Henny and Van Velzen, 1972). Often, breeding is delayed until 4 to 7 years of age in areas such as the Chesapeake Bay, where good nesting sites are scarce (Poole, 1989b). Henny and Wight (1969) observed mortality rates of 57.3 percent in first year osprey and 18.5 ± 1.8 percent in osprey of 2 to 18 years of age. Spitzer (1980) reported 41 percent annual mortality in juvenile osprey of both sexes and 15 percent in adults of both sexes. If osprey reach sexual maturity average longevity is 4.8 years (Brown and Amadon, 1968).

Reproduction/Breeding

Non-migratory (i. e., year-round resident) populations breed during the winter; whereas migratory populations breed during the summer (Poole, 1989a). Monogamy is the general rule for osprey; breeding pairs remain together and return to the same nest site year after year (Fernandez and Fernandez, 1977; Henny, 1988b). Colonies of osprey occur in areas such as islands, reservoirs, or lakes that offer secure nesting sites and abundant food (Henny, 1986), but most osprey are solitary nesters, often separated from other nests by tens to hundreds of kilometers (Poole, 1989a). Average clutch size is 2 to 4 eggs (Judge, 1983; Spitzer, 1980; Henny et al., 1991) with one clutch per year (Poole, 1989a).

The female performs most of the incubation and relies completely on the male for food from just after mating until the young have fledged (Poole, 1989a). Van Daele and Van Daele (1982) found that ospreys at successful nests incubated 99.5 to 100 percent of the daylight hours; disturbance of the nest during this time can kill the eggs if the adults are kept from returning to the nest for some time. Incubation lasts 32 to 43 days (Judge, 1983; Poole, 1989a). After hatching, the female is in constant attendance at the nest for the first 35 days but may perch nearby at intervals after that (Henny, 1988b). The female distributes the food delivered by the male by biting off pieces to feed to the young (Poole, 1989a). By 30 days, the nestlings have reached 70 to 80 percent of their adult weight and begin to be active in the nest (Poole, 1989a). The young fledge by age 60 to 65 days in nonmigratory populations and by about 50 to 55 days in migratory populations (Henny et al., 1991). After fledging, the young remain dependent on both parents for food usually for an additional 2 to 3 weeks (Poole, 1989a), but dependency can continue up to 6 weeks in the more southern populations (Henny, 1986). About 2 birds fledge per successful nest (Judge, 1983; Henny et al., 1991; Collopy, 1984; Henny et al, 1977.

Behavior and Social Organization

Osprey build large stick nests in the tops of tall trees or artificial structures such as buoys and radio towers (Poole, 1989a). In the Chesapeake Bay area, less than one third of the 1,450 breeding pairs built their nests in trees, while over half nested on channel markers and duck blinds, and the remainder on miscellaneous man-made structures (Henny et al., 1974). Osprey build their nest at the top of the chosen site, which can make it vulnerable to destruction from high winds (Henny, 1986). If not lost, the same nest often is used year after year, and it can become quite large (e. g., over 2 m tall and 1.5 m across) (Dunstan, 1973; Henny, 1988a). On islands where no predators are present, osprey will nest on the ground (Poole, 1989b).

Osprey are year-round residents in the most southern parts of their range (e. g., south Florida, Mexico) but are migratory over the rest of their range in the United States and Canada (Poole, 1989a). Studies of banded osprey have shown that the fall migration begins in late August in the north temperate zone, with adults and juveniles from the eastern and central United States comprising a broad front flying south and then directly across open ocean to their wintering grounds in Central and South America (Poole, 1989a). Spring migration appears to follow the same routes with birds reaching, for example, the Chesapeake Bay area in mid-March (Reese, 1977) and Minnesota by the first half of April (Dunstan, 1973; Henny and Van Velzen, 1972). The majority of migrating osprey appear to follow the coastline, perhaps because they come from coastal colonies or because the coast offers abundant food (Poole, 1989a). After their first migration south, juveniles remain in their wintering grounds for about a year and a half, returning north to the breeding grounds as 2-year-olds (Henny and Van Velzen, 1972). Fall migration usually peaks in September and ends in November (Henny, 1986).

3.3.8 Bald Eagle (Haliaeetus leucociphalus)[1]

The bald eagle (*Haliaeetus leucocephalus*) belongs to the order Falconiformes, family Accipitridae. Eagles have long rounded wings, large hooked bills, sharp talons, and are the largest birds of prey in the United States. They swoop down on their prey at high speeds, and their diet varies by species and considerably by habitat. In most species, the male is smaller than the female, but otherwise the sexes are similar in appearance. This family also includes kites and hawks. The bald eagle, our national symbol, is a federally designated endangered species. Relatively common in Alaska, populations in the lower 48 States have been seriously diminished, although they are recovering in some areas. Bald eagles are most commonly sighted in coastal areas or near rivers or lakes. Bald eagles are primarily carrion feeders.

Distribution

Bald eagles migrate out of areas where lakes are completely frozen over in winter, but will remain as far north as the availability of open water and a reliable food supply will allow (Brown and Amadon, 1968). Areas with ice-free waterways, such as the Columbia River estuary in Washington and Oregon, may support both resident and migratory populations in the winter (Watson et al., 1991). The far northern breeding populations migrate south for the winter and often congregate in areas with abundant food, particularly the Mississippi Valley and the northwestern States (Snow, 1973). Some populations of eagles that breed in southern latitudes (e. g., Arizona, Florida) show a reverse migration and migrate north in midsummer (following breeding), returning south in early autumn or winter (Brown and Amadon, 1968; Grubb et al., 1983).

Body Size and Weight

Females are significantly larger than males, but otherwise the sexes look alike (Brown and Amadon, 1968). Body size increases with latitude and is the sole basis by which the northern and southern subspecies are divided (Snow, 1973). Length from bill tip to tail tip averages 81 cm in the more northerly populations. Body weights for bald eagles from different locations throughout their range are presented in Table 3-63.

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1 All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

TABLE 3-63
Body Weights (g) for the Bald Eagles (*Haliaeetus leucocephalus)*

Location	Sex	Mean	Reference
Alaska	Female	5089	Imler & Kalmbach, 1955
	Male	4014	
Florida	Female	4500	Wiemeyer, 1991 (pers. Comm.)
	Male	3000	
Wisconsin	Egg	120.6±8.2	Krantz et al., 1970
Florida	Egg	102.5±17.9	Krantz et al., 1970
Saskatchewan, Canada	At Hatching	91.5±5.2	Bortolotti, 1984b
Saskatchewan, Canada	Nestlings		Bortolotti, 1984a,b
	Male 10 Days	500 (est.)	
	Male 30 Days	2700 (est.)	
	Male 50 Days	3600 (est.)	
	Male 60 Days	4066±35.1	
	Female 10 Days	500 (est.)	
	Female 30 Days	3000 (est.)	
	Female 50 Days	4600 (est.)	
	Female 60 Days	5172±46.5	

Food Habits and Diet Composition

Primarily carrion feeders, bald eagles eat dead or dying fish when available but also will catch live fish swimming near the surface or fish in shallow waters (Brown and Amadon, 1968). In general, bald eagles can be described as opportunistic feeders, taking advantage of whatever food source is most plentiful and easy to scavenge or to capture, including birds and mammals (Brown and Amadon, 1968; Green, 1985; Watson et al., 1991). In many areas, especially in winter, waterfowl, killed or injured by hunters, and shore birds are an important food source (Todd et al., 1982). Eagles forage in upland areas in the winter when surface waters are frozen over, consuming carrion including rabbits, squirrels, and dead domestic livestock such as pigs and chickens (Brown and Amadon, 1968; Harper et al., 1988). Bald eagles also have been known to steal food from other members of their own species as well as from hawks, osprey, gulls, and mergansers (Grubb, 1971; Jorde and Lingle, 1988; Sobkowiak and Titman, 1989). This may occur when there is a shortage of a primary food source, such as fish, and an abundance of other prey such as waterfowl being used by other predatory birds (Jorde and Lingle, 1988).

Some prey are important to a few populations; for example, in the Chesapeake Bay region, turtles are consumed during the breeding season (Clark, 1982), and at Amchitka Island in Alaska, sea otter pups are found regularly in bald eagle nests (Sherrod et al., 1975). In the Pacific Northwest during the breeding season, Watson et al. (1991) found that bald eagles hunted live prey 57 percent of the time, scavenged for 24 percent of their prey, and pirated 19 percent (mostly from gulls or other eagles). Because bald eagles scavenge dead or dying prey, they are particularly vulnerable to environmental contaminants and pesticides (e. g., from feeding on birds that died from pesticides, consuming lead shot from waterfowl killed or disabled by hunters) (Henny and Anthony, 1989; Harper et al., 1988; Lingle and Krapu, 1988). Bald eagles also are vulnerable to biomagnification of contaminants in food chains. For example, near Lake Superior (WI), herring gulls, which were consumed by over 20 percent of nesting bald eagle pairs, were found to be a significant source of DDE and PCB intake by the eagles (Kozie and Anderson, 1991). The gulls contained higher contaminant levels than the local fish because of their higher trophic level. Food preferences of Bald eagles are summarized in Table 3-64.

TABLE 3-64
Diet Composition of Bald Eagles *Haliaeetus leucocephalus)*

Location	Prey Taxon	Percent Volume	Reference
Washington-River	Mallard	32[a]	Fitzner & Hanson, 1979
	American Widgeon	9	
	American Coot	9	
	Other Birds	3	
	Chinook Salmon	21	
	Sucker	4	
	European Carp	1	
	Other Fish	1	
	Unaccounted	20	
Maine-Inland River	Brown Bullhead	24.8[b]	Todd et al., 1982
	White Sucker	19.5	
	Chain Pickerel	20.1	
	Smallmouth Bass	3.8	
	White Perch	3.6	
	Other Fish	4.9	
	Black Duck	3.0	
	Other Birds	13.5	
	Mammals	6.8	
Arizona-desert scrub, riparian	Fish	57.6[c]	Haywood & Ohmart, 1986

TABLE 3-64
Diet Composition of Bald Eagles *Haliaeetus leucocephalus)*

Location	Prey Taxon	Percent Volume	Reference
	Channel Catfish	21.8	
	Sonora Sucker	8.6	
	Carp	17.3	
	Other Fish	8.5	
	Birds	14.1	
	American Coot	8.1	
	Great Blue Heron	4.4	
	Mammals	28.1	
	Desert Cottontail	8.1	
	Jackrabbit	14.9	
	Rock Squirrel	1.1	
	Reptiles	0.2	
Alaska-Coastal	Pink Salmon	15.5[d]	Ofelt, 1975
	Herring	32.0	
	Trout	4.5	
	Other Fish	24.0	
	Other Animals	24.0	

[a] percent biomass; prey remains found below communal roost.
[b] percent occurrence in pellets.
[c] percent biomass; prey observed brought to nest or found at nests.
[d] percent frequency of occurrence; prey observed brought to the nest.

Food Consumption Rate

Captive bald eagles of all ages in Utah during winter consumed 0.092 ± 0.026 SD g salmon/g BW/day (Stalmaster and Gessaman, 1982). They also consumed 0.075 ± 0.013 SD g rabbit/g BW/day and 0.065 ± 0.012 SD g duck/g BW/day. Stalmaster and Gessaman (1984) also reported adult free-flying bald eagle food consumption in Washington as 0.12 g/g BW/day. Subadults consumed 0.10 g/g BW/day and juveniles consumed 0.091 g/g BW/day. Body weight was assumed to be 4.5 kg and it was not known if the bald eagles consumed food elsewhere. In Connecticut, free-flying adult bald eagles had a food consumption rate of 0.12 g/g BW/day and juveniles had a consumption rate of 0.14 g/g BW/day (Craig et al., 1988). Using Eq. 9 and a mean body weight of 4.15 kg (as calculated from the above table using adult birds), food ingestion was estimated at 0.009 kg/kg BW/day DW. Using Eq. 18 and assuming a diet of 16.5 percent birds, 6.8 percent mammals, and 76.7 percent fish (Todd et al., 1982) with water content of birds, mammals and fish of 67, 68, and 75 percent, respectively (Table 3-4), a fresh weight food consumption rate of 0.03 kg/kg BW/day can be calculated. (Note: If other body weight values are used, then the rate should be recalculated.)

Water Consumption Rate

No data concerning water consumption in bald eagles were available in the literature. Water consumption rates for adult female and adult male bald eagles of 0.035 L/kg BW/day and 0.037 L/kg BW/day, respectively, can be estimated using the Eq. 20 and body weights from Imler and Kalmbach (1955). (Note: If other body weight values are used, then the rates should be recalculated.)

Soil Ingestion

No information could be found in the literature concerning soil ingestion in bald eagles. Soil ingestion is likely to be negligible and consist only of that associated with prey that are consumed.

Respiration Rate

No data concerning inhalation rates among bald eagles were available in the literature. Inhalation rates of 0.28 m^3 air/kg BW/day for adult female bald eagles and 0.30 m^3 air/kg BW/day for adult males can be estimated using Eq. 22 and body weights from Imler and Kalmbach (1955). (Note: If other body weight values are used, then the rate should be recalculated.)

Metabolism

Craig et al. (1988) reported metabolic rates for bald eagles in Connecticut during the winter. The free-living rate for adults was 99 kcal/kg BW/day and 111 kcal/kg BW/day for juveniles. Metabolic rates in free-living bald eagles (females, 135 kcal/kg BW/day; males, 143 kcal/kg BW/day) can also be estimated using the equation from Nagy (1987) and body weights from Imler and Kalmbach (1955).

Habitat Requirements

Bald eagles generally are restricted to coastal areas, lakes, and rivers (Brown and Amadon, 1968), although some may winter in areas not associated with water (Platt, 1976). Preferred breeding sites include proximity to large bodies of open water and large nest trees with sturdy branches (often conifers) and areas of old-growth timber with an open and discontinuous canopy (Andrew and Mosher, 1982; Anthony et al., 1982; Grubb, 1980; Peterson, 1986). In an analysis of more than 200 nests, Grubb (1980) found 55 percent within 46 m of a shoreline and 92 percent within 183 m of shore. During migration and in winter, conifers often are used for communal roosting both during the day and at night, perhaps to minimize heat loss (Anthony et al., 1982; Stalmaster, 1980). Mature trees with large open crowns and stout, horizontal perching limbs are preferred for roosting in general (Anthony et al., 1982; Chester et al., 1990). Bald eagles reach maximum densities in areas of minimal human activity and are almost never found in areas of heavy human use (Peterson, 1986).

Home Range

During the breeding season, eagles require large areas in the vicinity of open water, with an adequate supply of nesting trees (Brown and Amadon, 1968). Distance from human disturbance is an important factor in nest site selection, and nests have been reported to fail as a result of disturbance (Andrew and Mosher, 1982). During incubation and brooding, eagles show territorial defense of an area around the nest site. Following fledging, there is little need for nest defense, and eagles are opportunistic in their search for abundant sources of prey (Mahaffy and Frenzel, 1987). During winter, eagles roost communally in large aggregations and share a foraging home range. For example, Opp (1980) described a population of 150 eagles that fed on meadow voles in a 250-ha flooded field for a 4-week period. This group also established a communal night roost in the vicinity. In spring, mating pairs in riparian desert areas of Arizona had territories of 3, 494 ± 2, 520 SD ha (Haywood and Ohmhart, 1983). Grubb (1980) reported mating pairs in Washington with territory lengths of 3.5 km (range, 1.4 – 7.2 km) and 15.8 km (range, 11.1 – 26.6 km). In 1987, Mahaffy and Frenzel (1987) reported territory radii of 0.56 ± 0.18 SE km for incubating pairs and 0.72 ± 0.21 SE km for brooding pairs in lakes and woods of Minnesota. In Missouri, juvenile eagles had winter home ranges of 1,830 ± 1,460 SD ha, while adults had winter home ranges of 1,880 ± 900 SD ha (Griffin and Baskett, 1985). Breeding bald eagles of all both sexes had winter foraging distances of 3 to 7 km in river habitats of Connecticut (Craig et al., 1988).

Population Density

Because population density depends strongly on the configuration of the surface water bodies used for foraging, few investigators have published explicit density estimates on an area basis; most report breeding densities along a shoreline on a linear basis. During the breeding season, 0.03 to 0.4 pairs have been recorded per km shore. Hansen (1987) reported 0.38 pair/km shore during the summer in Alaska. In contrast, Swenson et al. (1986) found much lower densities during summer in Wyoming (0.035 pair/km), Idaho (0.026 pair/km) and Montana (0.045 pair/km). Eagles migrating south from their summer territories in Canada have aggregated in communal roosts of up to 400 eagles in a 40-ha area (Crenshaw and McClelland, 1989). In the winter, communal roost sites may also contain large numbers of eagles. Opp (1980) described a group of 150 eagles that roosted and foraged together in the Klamath Basin (OR/CA), and communal night roosts of up to 300 eagles in Oregon in late winter.

Population Dynamics/Survival

Not all adults in an area are part of the breeding population. Some pairs may establish territories and not breed, while others may not even pair. The percentage of adults breeding and the breeding success of those that do breed vary with local food abundance, weather, and habitat conditions (Hansen, 1987; Hansen and Hodges, 1985; McAllister et al., 1986). In past years, bioaccumulation of organochlorine pollutants reduced the reproductive success of bald eagles. Now, in many areas, these raptors are reproducing at rates similar to those prior to the widespread use of these pesticides (Green, 1985). Eagles lay one clutch per year, although replacement clutches may be laid upon loss of the initial one (Sherrod et al., 1987). Very little is known about mortality rates of bald eagles; Grier (1980) concluded from population models that adult survival is more important than reproductive rate to the continued success of bald eagle populations. In Alaska, adults of both sexes experience annual mortality rates of only 5.4 percent, whereas young (fledging to 1 year) suffered 89.3 percent mortality (Sherrod et al., 1977). In captivity, bald eagles have lived for up to 50 years (Snow, 1973), and one wild eagle, banded and recaptured in Alaska, was estimated to be almost 22 years old (Cain, 1986).

Reproduction/Breeding

Bald eagles have been observed to nest successfully at 4 years of age, but most do not breed until at least their fifth year (Nye, 1983). Breeding pairs remain together as long as both are alive (Brown and Amadon, 1968). Large stick nests (approximately 1.5 m across and 0.6 m deep) are built near water and most often in a large tree, but sometimes on rocky outcrops or even on the ground on some islands (Brown and Amadon, 1968; Grubb, 1980). In the absence of disturbance, the same nest site may be used for many years (Nash et al., 1980). In Florida, eggs are laid in late autumn or winter, while over the rest of the eagle's range, mating and egg laying occur in spring (Brown and Amadon, 1968). One clutch per year is typical; however, bald eagles may lay replacement clutches upon loss of an initial clutch if sufficient time remains (Sherrod et al., 1987).

Clutch sizes average from 1 to 4 (Schmid, 1966-67), but are larger in the north (Brown and Amadon, 1968). Incubation lasts for 35 days (range, 34-38 days; Maestrelli and Wiemeyer, 1975), and both sexes take responsibility for feeding the young (Brown and Amadon, 1968). Young fledge at about 10 to 12 weeks of age (mean values of 79.9 days for males and 83 days for females in Saskatchewan; Bortolotti, 1989); after leaving the nest, they are still dependent on their parents for several weeks and often return to the nest for food (Sprunt et al., 1973). For every successful nest about 1 to 3 birds fledge (Schmid, 1966-67).

Behavior and Social Organization

After nesting, large groups will often gather at sites with plentiful food resources, such as along rivers following a salmon spawn (Fitzner and Hanson, 1979; Keister et al., 1987; McClelland, 1973). Additionally, large aggregates of bald eagles will gather in communal roosts when migrating south from the summer territories (Crenshaw and McClelland, 1989). Fall migration peaks in June in Arizona (Grubb et al., 1983) or as late as November in Montana and ends in mid-December (Crenshaw and McClelland, 1989). Both Keister et al. (1987) and Hodges et al. (1987) reported peaks in fall migration during December in Alaska, Oregon, and California. In Arizona, spring migration was noted to peak as early as December (Grubb et al., 1983) but doesn't peak until April for eagles in Oregon, California, Wyoming, Montana, and Idaho (Keister et al., 1987; Swenson et al., 1986).

3.3.9 Cooper's Hawk (*Accipiter cooperii*)[2]

The Cooper's hawk is in the order Falconiformes, family Acciptridae. Cooper's hawks are generally woodland species. They are intermediate in size between the other two congeneric accipiters in North America: the sharp-shinned hawk (*A. striatus*) and the northern goshawk (*A. gentilis*; Rosenfield and Bielefeldt, 1993).

Distribution

The Cooper's hawk is found in forested areas throughout the conterminous United States, southern Canada, and south to central Mexico (Rosenfield and Bielefeldt, 1993).

[2] Text directly from Sample et al. (1997a).

Body Size and Weight

The Cooper's hawk is medium sized (approximately that of a crow), with short, rounded wings and a long, rounded tail (Rosenfield and Bielefeldt, 1993). Males are significantly smaller than females (Storer, 1966). Birds in the eastern United States are larger than birds in the western United States. Body weights of Cooper's hawks are presented in Table 3-65.

TABLE 3-65
Body Weights (g) for the Cooper's Hawk (*Accipiter cooperii*)[a]

Location	Status	Sex	N	Mean ± STD
Eastern United States	Migrant	Male	51	349 ± 20
		Female	57	529 ± 36
	Breeding	Male	15	338 ± 20
		Female	31	566 ± 40
	Juvenile, migrant	Male	53	335 ± 26
		Female	58	499 ± 40
Western United States	Migrant	Male	177	281 ± 19
		Female	416	439 ± 35
	Breeding	Male	48	280 ◯ 19
		Female	20	473 ◯ 41
	Juvenile, migrant	Male	183	269 ◯ 22
		Female	310	399 ◯ 36
	Juvenile, breeding [b]	Male	9	276 ◯ 26
		Female	5	486 ◯ 29

[a] All data from Rosenfield and Bielefeldt (1993)
[b] nonbreeding, summer birds

Food Habits and Diet Composition

The diet of Cooper's hawks has been well studied. Sherrod (1978) and Rosenfield and Bielefeldt, 1993) provide reviews of literature concerning diet composition. In general, Cooper's hawks are reported to forage primary on medium-sized birds (approximately 60) suggest that the methods used in most dietary studies overestimate the proportion of birds in the diet and that small mammals may constitute the primary food. Species consumed include the American robin, jays, northern flicker, European starling, grouse, quail, pheasant, crows, doves, sparrows, chipmunks, hares, squirrels, deer mice, and bats. The diet composition of Cooper's hawks from several locations is presented in Table 3-66.

Cooper's hawks take prey ranging in size from 37 to 85 percent of their body weight (Rosenfield and Bielefeldt, 1993). Mean prey size taken by Cooper's hawks in eastern and western Oregon was 134.7 g and 136.3 g, respectively (Reynolds and Meslow, 1984). Males generally take smaller prey than females (Rosenfield, 1988). In Washington, the percentage of prey taken that was < 91 g was 81 percent for males and 65 percent for females (Kennedy and Johnson, 1986).

TABLE 3-66
Diet Composition of Cooper's Hawks *(Accipiter cooperii)*

Location	Prey Taxon	Percent	Comments	Reference
Northwestern Oregon	Birds ($\bar{x}_{size}$= 79.2g)	74	Diet composition determined from prey remains at nests. Species composition listed in appendix	Reynolds and Meslow, 1984
	Mammals ($\bar{x}_{size}$= 296.4g)	25		
Eastern Oregon	Birds ($\bar{x}_{size}$= 123.7g)	47		
	Mammals ($\bar{x}_{size}$= 147.5g)	43		
Northwest Washington	Birds	85	Diet composition determined by direct observation of prey deliveries to nests. Primary prey types were American robin and California quail	Kennedy and Johnson, 1986
	Mammals	15		
Michigan	Birds	84.4	Diet composition determined by analysis of gullet contents of nestlings and residues in nests	Hamerstrom and Hamerstrom, 1951
	Mammals	15.6		
New York and Pennsylvania	Birds	81.8	Diet composition determined from pellets prey remains at nests. Primary prey types were starlings, flickers, eastern meadowlarks, and chipmunks.	Meng, 1959
	Mammals	18.2		
Wisconsin	Birds	52 (42-60)[a]	Diet composition determined by crop content analysis	Bielefeldt et al., 1992
	Mammals	48 (40-58)[a]		
Michigan	Birds	29		
	Mammals	71		

[a] Mean and range of observations from three locations

Food Consumption Rate

Craighead and Craighead (1969) observed a food consumption of 0.197 g/g/d for a single male maintained in captivity during fall and winter. Average consumption by two females and a male, during spring and summer, was 0.165 g/g/d (range = 0.16 to 0.173; Craighead and Craighead, 1969). Using Eq.s 9 and 18, food ingestion rates of Cooper's hawks are estimated to range from 0.1 g/g/d to 0.13 g/g/d [assuming body weights of 566 g and 280 g (Table 3-65) and water content of birds and mammals of 68 percent (Table 3-4)].

Water Consumption Rate

No literature data were located concerning water ingestion rates for Cooper's hawks. Using Eq. 20, water ingestion rates of Cooper's hawks are estimated to range from 0.07 L/kg/d to 0.09 L/kg/d [assuming body weights of 566g and 280g (Table 3-65)].

Soil Ingestion

No literature data were located concerning soil ingestion by Cooper's hawks. Soil ingestion is likely to be negligible and consist only of that associated with prey that are consumed.

Respiration Rate

No literature data were located concerning inhalation rates for Cooper's hawks. Using Eq. 22, inhalation rates of Cooper's hawks are estimated to range from 0.47 m^3/kg/d to 0.55 m^3/kg/d [assuming body weights of 566g and 280g (Table 3-65)].

Metabolism

While generally viewed as "sit and wait" predators, accipiters are more active than previously thought. Consequently, their metabolic rates are generally higher than those observed in other Falconiformes (Kennedy and Gessaman, 1991). Mean metabolic heat production of male and female Cooper's hawks at rest are 2516.25 and 2655.50 mW, respectively (Kennedy and Gessaman, 1991).

Habitat Requirements

Cooper's hawks are a forest species, occurring in deciduous, mixed, and evergreen forests; floodplain forests; and wooded swamps (DeGraaf et al., 1981; Rosenfield and Bielefeldt, 1993). Forest edges are often used and may serve as primary hunting sites. They have also been observed to use urban habitats (Clark, 1977). Nesting habitat in Oregon was intermediate in both age and density of trees, relative to those used by sharp-shinned (younger and denser) and goshawks (older and more open; Reynolds et al., 1982). In the central Appalachians, the nest habitat of Cooper's hawks was characterized as mature forest with well developed understory and herb layer (Titus and Mosher, 1981).

Home Range

Cooper's hawks require considerable space. Home ranges during the breeding season may range from 400 to 1800 ha (Rosenfield and Bielefeldt, 1993). The mean size of winter ranges of four Cooper's hawks in Michigan was 192 ha (range=67 to 435 ha; Craighead and Craighead, 1969). Summer home range size for this population was highly variable, ranging from 18 to 531 ha; but mean size (203 ha) was comparable to that in winter.

Population Density

Density data for Cooper's hawks are based on the abundance of nests. As a consequence, the data are biased because nonbreeding individuals are not represented. Regardless, available data indicate this species to be diffuse throughout its range. Craighead and Craighead (1969) report densities of 0.017 pairs/ha in Michigan and 0.046 pairs/ha in Wyoming. In Oregon, mean density was 0.00045 pairs/ha (Reynolds and Wight, 1978).

Population Dynamics/Survival

Although eastern populations declined in the mid-1900s and the species is listed as threatened or endangered in several eastern states, evidence suggests the presence of recovering breeding populations in many areas (Rosenfield and Bielefeldt, 1993). Mean age at death reported from banding data was 16.3 months, with maximum longevity being 12 years. Mortality in the first year is 72 to 78 percent, then 34 to 37 percent in subsequent years (Rosenfield and Bielefeldt, 1993).

Reproduction/Breeding

Data on reproduction in Cooper's hawks was derived from DeGraaf et al. (1981), Palmer (1988), and Rosenfield and Bielefeldt (1993). Cooper's hawks nest in extensive forests, woodlots of 4 to 8 ha, and occasionally in isolated trees. Nests are constructed of sticks, placed in a main crotch or on a horizontal limb against the trunk of live trees, typically 10.7 to 13.7 m in height. Eggs may be present from May to June. Clutch sizes range from three to six eggs, but are typically four to five eggs. Incubation lasts 34 to 36 days. Hatching success ranges from 74 to 96 percent. The nestling period lasts 30 to 34 days for eastern birds and 27 to 30 days for western birds. Only one clutch/year is produced. Cooper's hawks generally do not breed until they are at least 2 years old.

Behavior

Cooper's hawks are diurnal, spending approximately 20 percent of the day hunting (Rosenfield and Bielefeldt, 1993). Birds from the northern portion of their range are migratory, although some stay resident year-round, even in Canada (Palmer, 1988). Southern birds may be locally migratory or more or less resident, leaving high elevations for more protected low elevations during winter.

Social Organization

Outside of the breeding season, Cooper's hawks are solitary. Small groups may form during migration, but these are incidental and are not the result of social interactions (Rosenfield and Bielefeldt, 1993).

3.3.10 Red-Tailed Hawk (*Buteo jamaicensis*)[1]

The red-tailed hawk (*Buteo jamaicensis*) belongs to the order Falconiformes, family Accipitridae. The family Accipitridae includes most birds of prey except falcons, owls, and American vultures. *Buteo* hawks are moderately large soaring hawks that inhabit open or semi-open areas. They are the most common daytime avian predators on ground-dwelling vertebrates, particularly rodents and other small mammals. They range in size from the broad winged hawk (41 cm bill tip to tail tip) to the ferruginous hawk (58 cm). Hawks egest pellets that contain undigestible parts of their prey, such as hair and feathers that can be useful in identifying the types of prey eaten (bones usually are digested completely; Duke et al., 1987). Nesting primarily in woodlands, red-tails feed in open country on a wide variety of small-to medium-sized prey.

[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

Distribution

The red-tailed hawk is the most common *Buteo* species in the United States (National Geographic Society, 1987). Breeding populations are distributed throughout most wooded and semiwooded regions of the United States and Canada south of the tundra (Adamcik et al., 1979), although some populations are found in deserts and prairie habitats. Six subspecies are recognized (Brown and Amadon, 1968).

Body Size and Weight

Males of this medium-sized *Buteo* (46 cm) weigh about 1 kg, and females are approximately 20 percent heavier than the males . Otherwise, the sexes look alike (Brown and Amadon, 1968). Body weights for Red-Tailed Hawks from different locations throughout their range are presented in Table 3-67.

TABLE 3-67
Body Weights (g) for the Red-Tailed Hawk (*Buteo jamaicensis)*

Location	Sex	Mean	Reference
Michigan, Pennsylvania	Female	1224	Craighead & Criaghead, 1956
	Male	1028	
Idaho	Female	1154	Steenhof, 1983
	Male	957	
Ohio	Female	1235	Springer & Osborne, 1983
	Male	1204	
	Hatchling Female	58	
	Hatchling Male	57	
	Juvenile Female	1149	
	Juvenile Female	962	

Food Habits and Diet Composition

Red-tails hunt primarily from an elevated perch, often near woodland edges (Bohm, 1978a; Janes, 1984; Preston, 1990). Small mammals, including mice, shrews, voles, rabbits, and squirrels, are important prey, particularly during winter. Red-tails also eat a wide variety of foods depending on availability, including birds, lizards, snakes, and large insects (Bent, 1937; Craighead and Craighead, 1956; Fitch et al., 1946). In general, red-tails are opportunistic and will feed on whatever species are most abundant (Brown and Amadon, 1968). Winter food choices vary with snow cover; when small mammals such as voles become unavailable (under the snow), red-tails may concentrate on larger prey, such as pheasants (Gates, 1972). Food preferences of Red-Tailed Hawks are summarized in Table 3-68.

TABLE 3-68
Diet Composition of Red-Tailed Hawks (*Buteo jamaicensis)*

Location	Prey Taxon	Percent Volume	Reference
Alberta, Canada-Farm & Woodlands	Summary of 10 years	Mean = SD	Adamcik et al., 1979
	Snowshoe hare	25.6±19[a]	
	Richard's Ground Squirrel	30.4±10	
	Franklin's Ground Squirrel	5.1±2	
	Voles & Mice	4.8±2	
	Other Mammals	7.8±6	
	Waterfowl	16.2±10	
	Ruffed Grouse	2.0±2	
	Sharp-tailed Grouse	1.2±1	
	Other Grouse	0.9±1	
	Other Birds	6.3±3	
Oregon-Pasture and wheat Fields	Mammals	78.5[b]	Janes, 1984
	Belding's Ground Squirrel	52.8	
	Mtn. Cottontail	13.1	
	Pocket Gopher	7.3	
	Townsend's Ground Squirrel	2.9	
	Birds	8.5	
	Alectoris Graeca	3.5	
	Western Meadowlark	1.8	
	Snakes	13.1	
	Gopher Snake	6.1	
California-foothills	Ground Squirrel	60.8[b]	Fitch et al., 1946
	Rabbit	26.5	
	Pocket Gopher	4.3	
	Other Mammals	2.6	
	Gopher Snake	3.8	
	Whiptail Lizard	0.3	
	Birds	1.3	

[a] percent wet weight of prey brought to chicks
[b] percent wet weight of prey brought to nests

Food Consumption Rate

Food consumption rates of adult female red-tailed hawks during winter were 0.11 g/g BW/day (Craighead and Craighead, 1956). Also, adult males consumed 0.10 g/g BW/day in winter and 0.086 g/g BW/day in summer. These birds were housed outdoors in Michigan using falconer's techniques. Using Eq. 9 and a mean body weight of 1.13 kg (as calculated from the above table using adult birds), a food consumption rate of 0.056 kg/kg BW/day was estimated. In order to calculate fresh weight, Eq. 18 was used and assumptions regarding diet were made. It was assumed that diet consisted of 78.5 percent mammals, 8.5 percent birds, and 13.1 percent snakes (Janes, 1984). Water content for each diet item was 68, 68, and 66 percent, respectively (Table 3-4). The estimated fresh weight food consumption rate was 0.154 kg/kg BW/day. (Note: If other body weight values are used, then the rate should be recalculated.)

Water Consumption Rate

No water consumption data were available for red-tailed hawks. A water consumption rate of 0.05 L/kg BW/day was calculated using Eq. 20 and a mean body weight of 1.13 kg. (Note: If other body weight values are used, then the rate should be recalculated.)

Soil Ingestion

No soil ingestion data were found in the literature. Soil ingestion is likely to be negligible and consist only of that associated with prey that are consumed.

Respiration Rate

No literature data were located concerning soil ingestion by red-tailed hawks. Using Eq. 22 an inhalation rate of 0.40 m^3 air/kg BW/day or 0.45 m^3air/day was estimated assuming a mean body weight of 1.13 kg. (Note: If other body weight values are used, then the rate should be recalculated.)

Metabolism

Breeding metabolic rate was found to be 109 kcal/kg BW/day in males and 102 kcal/kg BW/day in females inhabiting mountainous areas of California (Soltz, 1984). Pakpahan et al. (1989) determined standard metabolic rate to be 17.7 L O_2/kg-day using a metabolism chamber. Both basal and free-living metabolic rates can be estimated using the equations from Lasiewski and Dawson (1967) and Nagy (1987), respectively, and body weights from Craighead and Craighead (1956). Basal rates for males and females were 77 and 73 kcal/kg BW/day, while rates for free-living metabolism were 201 and 192 kcal/kg BW/day.

Habitat Requirements

Red-tails are found in habitats ranging from woodlands, wetlands, pastures, and prairies to deserts (Bohm, 1978b; Gates, 1972; MacLaren et al., 1988; Mader, 1978). They appear to prefer a mixed landscape containing old fields, wetlands, and pastures for foraging interspersed with groves of woodlands and bluffs and streamside trees for perching and nesting (Brown and Amadon, 1968; Preston, 1990). Red-tails build their nests close to the tops of trees in low-density forests and often in trees that are on a slope (Bednarz and Dinsmore, 1982). In areas where trees are scarce, nests are built on other structures, occasionally in cactus (Mader, 1978), on rock pinnacles or ledges, or man-made structures (Brown and Amadon, 1968; MacLaren et al., 1988). In winter, night roosts usually are in thick conifers if available and in other types of trees otherwise (Brown and Amadon, 1968).

Home Range

Red-tailed hawks are territorial throughout the year, including winter (Brown and Amadon, 1968). Trees or other sites for nesting and perching are important requirements for breeding territories and can determine which habitats are used in a particular area (Preston, 1990; Rothfels and Lein, 1983). Home range size can vary from a few hundred hectares to over 1,500 hectares, depending on the habitat (Andersen and Rongstad, 1989; Petersen, 1979). In a 10-year study in Oregon, Janes (1984) found that the size of red-tail territories and the location of boundaries between territories varied little from year to year, even though individual birds or pairs died and were replaced. Fitch et al. (1946) reported territory sizes of 60 – 160 ha for red-tailed hawks in California foothills during spring. In fields and woodlands of Michigan, red-tailed hawks had a mean territory size of 697 ± 316 SD ha during winter (Craighead and Craighead, 1956). Red-tailed hawks utilizing upland prairie and pinyon-juniper woodlands extended to 1, 770 ha (range, 957 – 2, 465) according to Anderson and Rongstad (1989).

Population Density

Population densities generally do not exceed 0.03 pairs/ha, and usually are lower than 0.005 pairs/ha. Populations in southern areas such as Florida can increase substantially in the winter with the influx of migrants from the more northerly populations (Bohall and Collopy, 1984). Population densities during the summer in Colorado were 0.0017 to 0.005 pairs/ha (McGovern and McNurney, 1986). In Michigan, densities ranged from 0.004 to 0.012 pairs/ha (Craighead and Craighead, 1956) with populations in Alberta having a mean of 0.0012 pairs/ha (Adamcik et al., 1979). In Toronto, during the winter, 0.014 hawks/ha were reported (Baker and Brooks, 1981) and Craighead and Craighead (1956) observed 0.0015 hawks/ha during the winter in Michigan.

Population Dynamics/Survival

Beginning at 2 years of age, most red-tailed hawks attempt to breed, although the proportion breeding can vary by population and environmental conditions (Henny and Wight, 1970, 1972). Average clutch size varies regionally, tending to increase from east to west and from south to north (Henny and Wight, 1970, 1972). In a 10-year study of red-tails in Alberta, Canada, Adamcik et al. (1979) found that the breeding population of adults remained stable despite strong cyclical fluctuations in the density of their main prey, the snowshoe hare, over the years. The mean clutch size for the red-tail population, however, appeared to vary with prey density, from 1.7 to 2.6 eggs/nest (Adamcik et al., 1979). Over the course of the study, about 50 percent of observed nestling losses occurred within 3 to 4 weeks after hatching due to starvation. Most of the variance in yearly mortality of nestlings could be attributed to the amount of food supplied and the frequency of rain. Large raptors such as horned owls also can be important sources of mortality for red-tail nestlings in some areas (Adamcik et al., 1979). Annual mortality rates were reported by Henny and Wight (1970, 1972) with a mean mortality of 62.4 percent for hawks in their first year found north of the 42 °N latitude in North America. Those south of the 42 °N latitude had a mean survival of 66 percent in the first year. Better survival was observed for adults of both sexes in the two locations (20.6 $\pm$ 1.3 SE and 23.9 $\pm$ 2.2 SE percent, respectively). The maximum known life span for the red-tailed hawk is 18 years (Henny and Wight, 1970, 1972).

Reproduction/Breeding

Mating in Arizona begins in mid-February and ends in early April (Mader, 1978), whereas mating in Alberta, Canada begins in mid-April and ends in mid May with the peak mating occurring in early May (Luttich et al., 1971). In south Michigan, mating starts in late March and continues through early April (Craighead and Craighead, 1956). Red-tails lay one clutch per year consisting of one to three eggs, although a replacement clutch is possible if the initial clutch is lost early in the breeding season (Bent, 1937). Mean clutch sizes of 2.0, 2.32, 2.2, 2.11, and 2.96 were recorded in California, Arizona, Alberta, Florida, and Oregon/Washington, respectively (Fitch et al., 1946; Mader, 1978; Adamcik et al., 1979; Henny and Wight, 1970, 1972.

Red-tailed hawk nests are large and built of twigs (Bohm, 1978b). Both sexes incubate, but the male provides food for the female during incubation and the entire family following hatching (Brown and Amadon, 1968). Incubation lasts 32 days (Adamcik et al., 1979) and fledging occurs within 45 to 46 days post-hatch (Fitch et al., 1946). The parents continue to feed their young after fledging while they are learning to hunt (Brown and Amadon, 1968). Henny and Wight (1970) reported that north of the 42 °N latitude the number of birds that fledge per successful nest is 2.12 compared to 1.85 south of the 42 °N latitude.

Behavior and Social Organization

The more northerly red-tailed hawk populations are migratory while the more southerly are year-round residents (Bent, 1937). Fall migration usually ends from mid-October to late November (Bent, 1937) with spring migration beginning as early as late February and peaking in early March (Craighead and Craighead, 1956; Bent, 1937; Luttich et al., 1971).

3.3.11 American Kestrel (*Falco sparverius*)[1]

The American kestrel (*Falco sparverius*) belongs to the order Falconiformes, family Falconidae. Falcons are the more streamlined of the raptor species, with long pointed wings bent back at the wrists and large tails that taper at the tips. They consume many kinds of animals including insects, reptiles, small mammals, and birds. Falcons are found in a variety of habitats, from cities to the most remote areas. Strong fliers that achieve high speeds, falcons range in size from the American kestrel (27 cm bill tip to tail tip) to the peregrine falcon (41 to 51 cm).

Distribution

The American kestrel, or sparrow hawk, is the most common falcon in open and semi-open areas throughout North America. There are three recognized subspecies: *F. s. paulus* (year-round resident from South Carolina to Florida and southern Alabama), *F. s. peninsularis* (year-round resident of southern Baja California), and *F. s. sparverius* (widespread and migratory) (Bohall-Wood and Collopy, 1986). The American kestrel is a year-round resident over most of the United States, but is migratory over the northern-most portions of its range

[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

(National Geographic Society, 1987). Because of their late molt, males migrate and arrive at the wintering grounds later than females or immatures (Smallwood, 1988).

Body Size and Weight

Weighing slightly over one tenth of a kilogram, the kestrel is the smallest falcon native to the United States (Brown and Amadon, 1968). As with most raptors, females are 10 to 20 percent larger than males (Bloom, 1973; Craighead and Craighead, 1956). Kestrel body weights vary seasonally, with maximum weight (and fat deposits) being achieved in winter and minimum weights in summer (Bloom, 1973; Gessaman and Haggas, 1987). Body weights for American Kestrels from different locations throughout their range are presented in Table 3-69.

TABLE 3-69
Body Weights (g) for the American Kestrel (*Falco sparverius)*

Location	Sex	Mean	Reference
California, Imperial Valley	Female-Fall	115±8.6	Bloom, 1973
	Female-Winter	132±13	
	Male-Fall	103±6.7	
	Male-Winter	114±7.8	
Utah	Female-Laying/Inc.	124	Gessaman & Haggas, 1987
	Female-Fall	127	
	Female-Winter	138	
	Male Incubate	108	
	Male-Fall	111	
	Male-Winter	119	

Food Habits and Diet Composition

Kestrels prey on a variety of small animals including invertebrates such as worms, spiders, scorpions, beetles, other large insects, amphibians and reptiles such as frogs, lizards, and snakes, and a wide variety of small-to medium-sized birds and mammals (Brown and Amadon, 1968; Mueller, 1987). Large insects, such as grasshoppers, are the kestrels' primary summer prey, although in their absence kestrels will switch to small mammals (Collopy, 1973) and birds (Brown and Amadon, 1968). In winter, small mammals and birds comprise most of the diet (Collopy and Koplin, 1983; Koplin et al., 1980). Kestrels usually cache their vertebrate prey, often in clumps of grass or in tree limbs and holes, to be retrieved later (Collopy, 1977; Mueller, 1987; Rudolph, 1982; Toland, 1984). Invertebrate prey usually are eaten immediately (Rudolph, 1982). In Florida, where small mammals are scarce and reptiles are abundant, lizards are an important component of the diet (Bohall-Wood and Collopy, 1987). Kestrels forage by three different techniques: using open perches from which to spot and attack ground prey, hovering in the air to spot ground prey, and catching insects on the wing (Rudolph, 1982, 1983). Food preferences of American kestrels are summarized in Table 3-70.

TABLE 3-70
Diet composition of American Kestrels *(Falco sparverius)*

Location	Prey Taxon	Percent Volume	Reference
California-open areas, woods	Invertebrates	32.6[a]	Meyer & Balgooyen, 1987
	Mammals	31.7	
	Birds	30.3	
	Reptiles	1.9	
	Other	3.5	
Florida-dry pine-oak woodlands (sandhill)	Vertebrates (primarily lizards)	49[a]	Bohall-Wood & Collopy, 1987
	Invertebrates	51	
California-hayfields, pasture	Coleoptera	10.8[a]	Collopy & Koplin, 1983
	Other Invertebrates	14.2	
	Frogs (*Rana aurora*)	8.0	
	Other Herpetofauna	12.2	
	Microtus californicus	30.2	
	Sorex vagrans	9.4	
	Other Mammals	11.5	

[a] Percent wet weight of prey observed captured.

Food Consumption Rate

Free-living American kestrels in northwest California during winter had food consumption rates of 0.29 g/g BW/day (Koplin et al., 1980). Koplin et al. (1980) further divided the food consumption by prey type with 0.18 g/g BW/day of vertebrate prey and 0.11 g/g BW/day of invertebrate prey. In summer adult males in semi-natural enclosures in Ohio consumed 0.31 g/g BW/day (Barrett and Mackey, 1975). Using Eq. 9 and a mean body weight of 0.119 kg (as calculated from Table 3-69 using only adult birds) the estimated food consumption was 0.12 kg/kg BW/day. To calculate a fresh weight, a diet of 31.7 percent mammal, 32.6 percent invertebrates, 30.3 percent birds, and 1.9 percent reptiles (Meyer and Balgooyen, 1987) with respective water contents of 68, 69, 68, and 66 percent (Table 3-4) was used. Using Eq. 18 the estimated fresh weight food consumption is 0.26 kg/kg BW/day. (Note: If other body weight values are used, then the rates should be recalculated.)

Water Consumption Rate

No data concerning water ingestion in American kestrels were available in the literature. Water consumption rates of 0.11 and 0.12 L/kg BW/day for adult females and males, respectively, can be estimated using Eq. 20 and body weights from Gessaman and Haggas (1987). (Note: If other body weight values are used, then the rates should be recalculated.)

Soil Ingestion

No information was found in the literature concerning soil ingestion in American kestrels. Soil ingestion is likely to be negligible and consist only of that associated with prey that are consumed.

Respiration Rate

No data concerning inhalation rates for American kestrels were available in the literature. Inhalation rates of 0.66 m^3 air/kg BW/day for adult female bald eagles and 0.68 m^3 air/kg BW/day for adult males can be estimated using Eq. 22 and the mean body weights for males and females presented above. (Note: If other body weight values are used, then the rate should be recalculated.)

Metabolism

Free-living metabolic rate in American kestrels was reported by Gessaman and Haggas (1987) for males and females during laying/incubation, fall, and winter in Utah. Respective rates for males were 337.6, 364.9, and 386.4 kcal/kg BW/day, while females had rates of 414.4, 368.7, and 327.2 kcal/kg BW/day. Both basal metabolic rates for males and females can be estimated using an equation presented in Lasiewski and Dawson (1967) and body weights from Gessaman and Haggas (1987). Free-living rates can be calculated using the same body weights but equations from Nagy (1987). Basal metabolism was 134 kcal/kg BW/day for females and 140 kcal/kg BW/day for males, while free-living metabolism was 333 and 345 kcal/kg BW for females and males, respectively.

Habitat Requirements

Kestrels inhabit open deserts, semi-open areas, the edges of groves (Brown and Amadon, 1968), and even cities (National Geographic Society, 1987). In several areas, investigators have found that male kestrels tend to use woodland openings and edges, while females tend to utilize more open areas characterized by short or sparse ground vegetation, particularly during the winter (Koplin, 1973, cited in Mills, 1976; Meyer and Balgooyen, 1987; Mills, 1975, 1976; Smallwood, 1987). In other areas, however, investigators have found no such differentiation (Toland, 1987; Sferra, 1984). In Florida, kestrels appear to prefer sandhill communities (particularly pine/oak woodlands); these areas provide high-quality foraging habitat and the majority of available nest sites (Bohall-Wood and Collopy, 1986). Kestrels are more likely to use habitats close to centers of human activities than are most other raptors (Fischer et al., 1984).

Home Range

Although some investigators have not noted territorial defense (e. g., Craighead and Craighead, 1956), Mills (1975) demonstrated that kestrels defend territories by introducing captured birds into other birds' territories. Winter foraging territories range from a few hectares in productive areas (e. g., in California) (Meyer and Balgooyen, 1987) to hundreds of hectares in less productive areas (e. g., Illinois, Michigan) (Craighead and Craighead, 1956; Mills, 1975). Summer breeding territories probably follow the same pattern (Craighead and Craighead, 1956). The winter territory of adult females was 31.6 ± 10.7 SD ha in open areas and woods of California, while the winter territory of adult males was 13.1 ± 2.0 SD ha (Meyer and Balgooyen, 1987). The mean territory for all kestrels in open areas and woodlands of California was 154 ha (range, <452 ha). The summer territory of adult kestrels in Wyoming grasslands and forests was 202 ± 131 SD ha and in woodlots and fields of Michigan was 131 ± 100 SD ha (Craighead and Craighead 1956).

Population Density

Although much smaller than red-tailed hawks and bald eagles, reported kestrel breeding population densities can be similarly low (e. g., 0. 0003 to 0.004 nest/ha). Population densities in urban Missouri were reported as 0.0026 nest/ha with rural densities reported as 0.0004 nests/ha (Toland and Elder, 1987). In Wyoming grasslands and forests, Craighead and Craighead (1956) found densities of 0.0035 pairs/ha in the summer. In Michigan, they also reported densities during fall, winter and spring (0.0007, 0.0005, and 0.0010 pairs/ha, respectively).

Population Dynamics/Survival

Kestrels are sexually mature in the first breeding season after their birth (Carpenter et al., 1987). Scarcity of suitable nesting cavities probably limits the size of kestrel populations in parts of the United States (Cade, 1982). Three to four young may fledge per nest per year, but mortality of juveniles in the first year is high (60 to 90 percent) (Craighead and Craighead, 1956; Henny, 1972). Predators of the kestrel include large raptors such as great horned owls, golden eagles, and red-tailed hawks (Meyer and Balgooyen, 1987). Adult mortality can be low (e.g., 12 percent/year; Craighead and Craighead, 1956); however, Henny (1972) reported an average mortality of 46.0 ± 4.6 SE percent in North American kestrel adults of both sexes. In the same study, juveniles of both sexes suffered 60.7 percent annual mortality. In captivity, kestrels have been known to live up to 9 years (Carpenter et al., 1987).

Reproduction/Breeding

Kestrels typically build their nests in tree cavities, but have used holes in telephone poles, buildings, or stream banks when tree cavities are not available (Brown and Amadon, 1968). One clutch per year is standard (Carpenter et al., 1987) with an average clutch of 4 to 5 eggs (range, 3-7 eggs; Brown and Amadon, 1968). Mean clutch size for American kestrels inhabiting the juniper, sagebrush habitats of California was 4.3 eggs (Bloom and Hawks, 1983). Both parents participate in incubation, but the female performs most of the incubation, while the male provides her with food (Brown and Amadon, 1968). Incubation has been reported to last 33 to 35 days (mean, 33.7 □ 0.33 SE days) in captivity (Porter and Wiemeyer, 1972) and 29 to 30 days in another study (Brown and Amadon, 1968). Following hatching, the male brings the majority of the prey to the nestlings (Brown and Amadon, 1968). Fledging occurs from 26 to 30 days post-hatch (mean, 27.4 days; Porter and Wiemeyer, 1972). The mean number of birds that fledge per successful nest was reported as 3.7 by Bloom and Hawks (1983). This was very close to the number reported for active nests (3.1 fledged/active nest), suggesting that nesting success is quite high for kestrels nesting in juniper/sagebrush areas. Moreover, Craighead and Craighead (1956) reported 3.8 chicks fledged per active nests indicating that the grasslands and forested regions of Wyoming are even more productive. After fledging, young kestrels remain dependent on their parents for food for at least 2 to 4 additional weeks (Lett and Bird, 1987).

Behavior and Social Organization

Adult kestrels are solitary, except during the breeding season, and maintain territories even in winter (Brown and Amadon, 1968). Fledglings often perch and socialize with their siblings prior to dispersal (Lett and Bird, 1987). In Florida, resident kestrels (paulus subspecies) maintain year-round pair bonds and joint territories. The resident pairs have a competitive advantage over winter migrants (sparverius subspecies) in their territories (Bohall-Wood and Collopy, 1986). In northern Utah fall migration starts in early September and ends in early November (Gessamen and Haggas, 1987). In south Michigan and Wyoming, Craighead and Craighead (1956) reported spring migration to occur in early March or mid-April, respectively.

3.3.12 Wild Turkey (Meleagris gallopavo)[3]

The wild turkey is in the order Galliformes, family Phasianidae. It is related to the chukar, curassow, ruffed grouse, quail, red jungle fowl, spruce grouse, and ring-necked pheasant. There are six subspecies. *M .g. mexicana* is the largest of the subspecies and *M .g. gallapavo* is the smallest subspecies. *M. g. merriami* and *M. g. silvestris* are larger than *M. g. intermedia*. Wild turkeys are strong short distance fliers and socially complex birds with numerous vocal signals. They are native to eastern North America but have been widely introduced as game species throughout the world.

Distribution

The wild turkey has one of the widest distributions among game birds of North America. They are found from southern Canada through the contiguous 48 states and south into Mexico. They are most common and widespread in their original native range in the eastern United States, but numerous introduced populations have expanded the range westward and they have been widely introduced throughout the world as domestic birds (Eaton, 1992).

Body Size and Weight

Males are generally larger than females, however, body size is highly variable among subspecies, individuals, age, season, and location. In moderate climates the yearly body mass generally fluctuates between 15 and 20 percent, with maximal weight in adults achieved during the winter months, prior to breeding, and minimal weights in the summer during molt (Eaton, 1992). Body weights are presented in Table 3-71.

Food Habits and Diet Composition

Vegetable matter accounts for nearly 97 percent of the wild turkey's diet with the remaining 3 percent made up of animal matter, primarily invertebrates. Feeding activity is bimodal with a peak in the early morning, beginning shortly after dawn, and again in the evening,

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[3] New species accounts compiled for ARAMS.

two to three hours before sunset. They are extremely adaptable and nondiscriminatory in their diet. They forage on the ground, generally in flocks.

TABLE 3-71
Body Weights (kg) for the Wild Turkey *(Meleagris gallopavo)*

Time of Year	Sex / Age	N	Mean	Minimum	Maximum	Reference
Jan-Mar	Male / Adult	140	7.8	6.1	10.4	Eaton, 1992
	Male / Yearling	132	5.4	3.9	7.6	
	Female / Adult	182	4.3	3.2	6.5	
	Female / Yearling	167	3.9	2.5	4.5	
May	Male / Adult	44	8.4	6.3	10.4	Rende, 1983
	Male / Yearling	32	6.7	5.0	8.8	
Aug-Sep	Male / Adult	14	7.3	6.5	8.6	Eaton, 1992
	Male / Yearling	14	7.6	6.5	8.4	
	Female / Adult	64	4.0	3.4	4.6	
	Female / Yearling	73	3.7	3.2	4.5	
Oct-Nov	Male / Adult	5	8.4	6.6	9.5	Eaton, 1992
	Male / Yearling	12	5.3	3.9	6.3	

TABLE 3-72
Diet Composition of the Wild Turkey *(Meleagris gallopavo,* Identified from Droppings Collected Between July 1946 and April 1947 (Glover and Bailey, 1949)

Location	Food Items	Percent Frequency	Percent Total Volume
West Virginia	Vegetable Matter		98.32
	Wild Oats	28.0	21.46
	Corn	36.9	16.23
	Grasses	31.0	12.30
	Beechnuts	17.6	11.05
	Beechbuds	20.7	9.90
	Ferns	25.4	9.72
	Hemlock Needles	9.0	3.66
	Bryophytes	7.1	3.19

TABLE 3-72
Diet Composition of the Wild Turkey *(Meleagris gallopavo*, Identified from Droppings Collected Between July 1946 and April 1947 (Glover and Bailey, 1949)

Location	Food Items	Percent Frequency	Percent Total Volume
	Wild Grape	4.1	2.80
	Dogwood	16.4	2.20
	Blackberry	14.7	2.14
	Wild Cherry	7.4	0.96
	Wild Raisin	4.9	0.93
	Wild Indigo	3.9	0.66
	Greenbrier	3.8	0.31
	Hawthorn	3.6	tr.
	Smartweed	3.6	tr.
	Witch Hazel	2.5	tr.
	Wild Rose	1.7	tr.
	Birch Buds	0.7	tr.
	Partridgeberry	0.7	tr.
	Animal Matter		1.60
	Beetles	5.6	tr.
	Stink Bugs	1.7	tr.
	Insect Cocoons	0.3	tr.
	Antsand Wasps	0.2	tr.
	Millipedes	0.2	tr.
	Grasshoppers	0.1	tr.

Food Consumption Rate

The feeding rate for an average wild turkey is between 30 and 56 g/kg BW/day or 0.3 to 0.56 kg/kg BW/day (Korschgen, 1967; Decker et al., 1991); however, individual birds will gorge themselves on choice food items when available. Using Eq. 9, and assuming a mean body weight of 6.7 kg (as calculated using adult body weights from Table 3-71) a food consumption rate of 0.03 kg/kg BW/day can be calculated. A fresh weight (0.13 kg/kg BW/day) can be estimated assuming a diet of 100 percent vegetable matter with water content of 77 percent as presented in Table 3-4. (Note: If other body weight values are used, then the rate should be recalculated.)

Water Consumption Rate

Wild turkeys require water once or twice daily and will seldom roost or nest more than 1.6 to 3.2 km from a permanent water source (Zeiner et al., 1990b). Water quality does not appear to be as critical as availability of a water source within the daily range of the birds (Eaton, 1992). Using Eq. 20 and a body weight of 6.7 kg, a water consumption rate of 0.03 L/kg BW/day can be estimated. (Note: If other body weight values are used, then the rate should be recalculated.)

Soil Ingestion Rate

Grit is required by turkeys for grinding food items in the gizzard. Turkeys appear to be able to control the amount of grit in the gizzard and constant replacement is not required. Estimates of grit in the stomach content range between 3 and 35 c^3 with an average of 18 c^3 in the stomach (Korschgen, 1967). Beyer et al. (1994) presented a soil ingestion of 9.3 percent of diet for the wild turkey.

Metabolism

The rate of oxygen consumption (VO_2) was obtained using an equation from Hill (1972). For winter juveniles the rate was determined to be 0.398 ± 0.010. For winter adults the rate was 0.423 ± 0.005. The summer adult oxygen consumption rate was 0.336 ± 0.005. Despite the fact that males are nearly twice the size of females, there were no differences in rate/g body mass between the sexes (Gray and Prince, 1988). Additional metabolic rates are presented in Table 3-73.

TABLE 3-73
Standard Metabolic Rate (SMR; mL 0_2/g BW/hr) and Lower Critical Temperature for Adult Turkeys (*Meleagris gallopavo)*, in New Hampshire, from Oberlag et al., 1990.

				SMR		
Season	**Sex**	**n**	**Mass (g)**	**Mean**	**SE**	T_{lc}
Winter	M	4	10,320	0.453	0.010	-13.5
	F	4	4,900	0.460	0.025	-16.2
Spring	M	4	10,610	0.340	0.006	2.2
	F	3	4,640	0.449	0.018	0.0
Summer	M	4	9,430	0.410	0.015	11.7
	F	4	4,020	0.449	0.02	13.7
Autumn	M	6	8,570	0.451	0.011	-4.9
	F	6	4,190	0.490	0.009	-2.2

Respiration Rate

No information was found in the literature for turkeys on respiration rates. Using Eq. 22 and assuming a body weight of 6.7 kg, a respiration rate of 0.26 m^3/kg BW/day can be calculated. (Note: If other body weight values are used, then the rate should be recalculated.)

Habitat Requirements

Wild turkeys appear to use a variety of woodland and grassland habitats but prefer mature stands of mixed hardwoods and conifers with relative open understories, scattered clearings, and available food and water sources. They typically roost in large trees with horizontal limbs and open canopies such as oaks and pines (Boeker and Scott, 1969). Nests are constructed on the ground in areas with moderately dense vegetation to conceal the nest site (Eaton, 1992).

Home Range

The size of the home range is highly variable and is determined by a number of factors including habitat productivity, local population density, site management history, and food abundance. Within an individual home range, there are widely separated areas of activity with some areas more heavily utilized than others. Home ranges have been reported as small as 65 ha in Minnesota to as much as 683 ha in Michigan (Lewis, 1963). Other studies have reported home rages between 365 and 7775 ha for males and between 304 and 405 ha for females (Kurzejeski and Lewis, 1990). In Arkansas average home ranges were reported to be 3.51 ha (Wigley et al., 1986).

Population Density

Overhunting and habitat loss resulted in dramatic population declines in the late 19th and early 20th century, but game management and reintroduction programs have significantly increased the population. In 1990, the population in the United States and Canada was estimated at 3.5 million birds. Generally wild turkeys occur in low densities of 1 to 5 birds/Km, over large areas (Eaton, 1992). The mean wild turkey density in southern Texas was 5.9 birds/km^2 (Emlen, 1972). In northern Missouri population densities may be as high as 30 birds/km^2 (Vangilder and Kurzejeski, 1995). There are a number of factors that affect population density, including elevation, topography, accessibility, and general location of the habitat type. Oak woodlands, mixed hardwood, and oak-pine woodlands support the highest densities of wild turkeys (Uhlig and Baily, 1952).

Population Dynamics / Survival

The principle factors limiting wild turkey populations are early poult mortality, availability of suitable habitat and hunter harvest. Usually there is one clutch per breeding season, however, if a nest is lost soon after laying a hen will often renest. Few hens renest if a nest is lost after long incubation periods and no hens renest if the nest is lost after the eggs have hatched (Williams, 1981). The average clutch size for wild turkeys in New York state was 12 to 15 (Glidden, 1977). Nesting success for turkeys ranges between 30 and 70 percent (Porter et al., 1983; Vangilder et al., 1987). Severe winters reduce egg hatching success as well as yearling survival (Williams and Austin, 1988). Poult loss to predation is greatest during the first 14 days when roosting on the ground (Porter et al., 1983). The average life expectancy is between 1.3 and 1.6 years, with turnover of cohorts ranging between 2.78 and 8.17 years. The annual mortality rates are between 60 and 76 percent (Mosby, 1967). Wild turkeys have been found to live up to at least 13 years (Williams and Austin, 1988).

Reproduction and Breeding

Breeding generally begins in late February and may extend into early April. Year old birds are sexually mature and females will mate during their first spring, but young males often can't compete with older males. Males are polygamous and a dominant gobbler will often breed with as many as 12 females. Eggs are generally laid in late April and have an incubation period of 27 to 31 days. Nest sites are located on the ground, and consist of a simple depression in dead leaves or litter, usually in dense vegetation, under shrubs or at the base of a tree. Vegetative cover that provides a high degree of visible obstruction is important in nest site selection (Rumble and Hodorff, 1993; Day et al., 1991). After mating, the male departs and nest construction, brooding eggs, and rearing young is done solely by the female (Eaton, 1992).

Behavior

Wild turkeys are strong short distance fliers, but can only fly a maximum of one mile in a single flight. They spend most of their time walking. Wild turkeys are excellent runners and the males will typically run from danger, while the females typically take to flight to escape danger. Roosting in tall trees begins soon after sunset and fly down occurs shortly after sunrise. The hours immediately after fly down and prior to roosting are spent foraging (Eaton, 1992).

Social Organization

Wild turkeys usually roost in flocks, but will also roost singly. During the fall, the male flocks vary between 1 to 9 gobblers and the females may flock in groups as large as 40 birds. During the winter, the females break up into smaller groups, usually four birds, and are joined by a male. Following copulation the females separate from the males. Each sex forms independent hierarchies. The female hierarchies tend to be relatively stable, but the males frequently change dominance. In the male flocks, ranking is not only established among individuals, but also among different groups of males, whereas the females only establish ranking among individuals (Eaton, 1992).

3.3.13 Northern Bobwhite (*Colinus virginianus*)[1]

Northern bobwhite (*Colinus virginianus*) belong to the order Galliformes and family Phasiadinae. Quail are ground-dwelling birds with short, heavy bills adapted for foraging on the ground for seeds and insects. Most species inhabit brush, abandoned fields, and open woodlands; some inhabit parklands. Quail and most other gallinaceous birds are poor flyers that seldom leave the ground and do not migrate. All species of this family gather in coveys (i.e., flocks of varying size) during some part of the year. Quail range in size from Montezuma's quail (22 cm bill tip to tail tip) to the mountain and Gambel's quail (28 cm); sexes are similar in size but differ in appearance. The northern bobwhite feeds mainly on seeds by gleaning on the ground and low vegetation.

Distribution

It ranges from southeastern Wyoming, east to southern Minnesota and across to southern Maine, south through the central and eastern United States to eastern New Mexico in the

[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

west and to Florida in the east (American Ornithologists' Union, 1983). It is the most widespread of the North American quail and used to be very common, particularly east of the Rocky Mountains. Over the past three decades, however, populations have been declining throughout its range (Brennan, 1991).

Body Size and Weight

Northern bobwhite are average-sized quail (25 cm), and wild bobwhites typically weigh between 150 and 200 g depending on location and season while commercially bred stock usually exceed 200 g and may reach 300 g or more (Brenner and Reeder, 1985; Koerth and Guthery, 1991). Males and females are similar in size, and weights tend to increase with latitude and toward the west coast of the United States (Hamilton, 1957; Rosene, 1969; Roseberry and Klimstra, 1971). Females are heaviest in the spring and summer when they are laying eggs; males are lightest at this time of year (Hamilton, 1957; Roseberry and Klimstra, 1971). Juveniles tend to weigh slightly less than adults through winter (Hamilton, 1957; Roseberry and Klimstra, 1971). Koerth and Guthery (1987) found both males and females to maintain between 9 and 11 percent body fat (as a percentage of dry body weight) throughout the year in southern Texas; more northern populations may maintain higher body fat ratios, particularly just prior to breeding (McRae and Dimmick, 1982) . Body weights for Northern Bobwhites from different locations throughout their range are presented in Table 3-74.

TABLE 3-74
Body Weights (g) for the Northern Bobwhite (*Colinus virginianus)*

Location	Sex	Mean	Reference
Kansas	Both-Fall	189.9±3.28	Robel, 1969
	Both-Winter	193.9±4.56	
	Both-Spring	190.0±4.98	
Illinois	Male-Winter	181	Roseberry & Klimstra, 1971
	Male-Summer	163	
	Female-Winter	183	
	Female-Summer	180	
West Rio Grande, Texas	Male-Winter	161	Guthery et al., 1988
	Male-Summer	154	
	Female-Winter	157	
	Female-Summer	157	
Georgia-Both Captive And Wild Birds Living In Farms, Woods, And Thickets	At Hatching	6.3	Stoddard, 1931
	Day 6	9-10	

TABLE 3-74
Body Weights (g) for the Northern Bobwhite (*Colinus virginianus)*

Location	Sex	Mean	Reference
	Day 10	10-13	
	Day 19	20-25	
	Day 32	35-45	
	Day 43	55-65	
	Day 55	75-85	
	Day 71	110-120	
	Day 88	125-150	
	Day 106	140-160	
Kansas	Both-Fall	174.0-3.49	Robel, 1969

Food Habits and Diet Composition

Bobwhites forage during the day, primarily on the ground or in a light litter layer less than 5 cm deep (Rosene, 1969). Seeds from weeds, woody plants, and grasses comprise the majority of the adult bobwhite's diet throughout the year (Handley, 1931; Bent, 1932; Lehmann, 1984), although in winter in the south, green vegetation has been found to dominate the plant materials in their diet (Campbell-Kissock et al., 1985). Insects and other invertebrates can comprise up to 10 to 25 percent of the adults' diet during the spring and summer in more northerly areas and year-round in the south (Campbell-Kissock et al., 1985; Handley, 1931; Lehmann, 1984). Insects comprise the bulk of the chicks' diet; up to 2 or 3 weeks of age chicks may consume almost 85 percent insects, the remainder of the diet consisting of berries and seeds (Handley, 1931). Most insects consumed by bobwhite chicks are very small, less than 8 mm in length and 0.005 g (Hurst, 1972). Juvenile bobwhite, on the other hand, may consume only 25 percent insects, the remainder of their diet being fruit and seeds (Handley, 1931). Quail consume little grit. Korschgen (1948) found grit in only 3. 4 percent of over 5, 000 crops examined, and agreed with Nestler (1946) that hard seeds can replace grit as the grinding agent for northern bobwhite. Food preferences of northern bobwhites are summarized in Table 3-75.

TABLE 3-75
Diet Composition of Northern Bobwhites (*Colinus virginianus)*

Location	Prey Taxon	Percent Volume	Reference
Southeastern United States-NS[a]			Handley, 1931
Spring	Total Plant Foods	87.2[b]	
	Misc. Seeds	21.1	
	Other Seeds:		

TABLE 3-75
Diet Composition of Northern Bobwhites (*Colinus virginianus)*

Location	Prey Taxon	Percent Volume	Reference
	Legumes	15.2	
	Senna	7.2	
	Cultivated Plants	2.1	
	Grasses	3.1	
	Sedges	1.1	
	Mast	14.1	
	Spurges	0.1	
	Fruit	11.1	
	Forage Plants	12	
	Total Animal Foods	12.8	
	Grasshoppers	3.2	
	Bugs	2.8	
	Beetles	4.6	
Summer	Total Plant Foods	78.7	
	Misc. Seeds	6.0	
	Other Seeds:		
	Legumes	3.9	
	Senna	0.4	
	Cultivated Plants	2.1	
	Grasses	11.3	
	Sedges	1.2	
	Mast	0.2	
	Spurges	1.2	
	Fruit	45.8	
	Forage Plants	0.3	
	Total Animal Foods	19.6	
	Grasshoppers	7.5	
	Bugs	4.4	
	Beetles	6.3	

TABLE 3-75
Diet Composition of Northern Bobwhites (*Colinus virginianus)*

Location	Prey Taxon	Percent Volume	Reference
Fall	Total Plant Foods	79.7	
	Misc. Seeds	11.1	
	Other Seeds:		
	Legumes	10.1	
	Senna	0.2	
	Cultivated Plants	5.3	
	Grasses	26.0	
	Sedges	2.4	
	Mast	0.5	
	Spurges	5.5	
	Fruit	11.3	
	Forage Plants	0.3	
	Total Animal Foods	20.3	
	Grasshoppers	16.6	
	Bugs	0.6	
	Beetles	0.8	
Winter	Total Plant Foods	96.8	
	Misc. Seeds	2.6	
	Other Seeds:		
	Legumes	31.5	
	Senna	12.8	
	Cultivated Plants	2.6	
	Grasses	2.3	
	Sedges	1.1	
	Mast	28.0	
	Spurges	0.4	
	Fruit	9.5	
	Forage Plants	5.2	
	Total Animal Foods	3.2	
	Grasshoppers	2.4	

TABLE 3-75
Diet Composition of Northern Bobwhites (*Colinus virginianus)*

Location	Prey Taxon	Percent Volume	Reference
	Bugs	0.1	
	Beetles	0.2	
South Texas-Semi-prairie, Brushland			Lehmann, 1984
Spring	Seeds of Weeds	43.64[c]	
	Seeds of Woody Plants	4.03	
	Seeds of Grasses	13.2	
	Cultivated Grains, etc.	3.7	
	Greens	27.4	
	Insects	8.03	
Summer	Seeds of Weeds	33.7	
	Seeds of Woody Plants	20.5	
	Seeds of Grasses	24.8	
	Cultivated Grains, etc.	1.9	
	Greens	4.9	
	Insects	14.2	
Fall	Seeds of Weeds	30.0	
	Seeds of Woody Plants	39.7	
	Seeds of Grasses	0.7	
	Cultivated Grains, etc.	8.3	
	Greens	3.4	
	Insects	17.9	
Winter	Seeds of Weeds	34.3	
	Seeds of Woody Plants	9.5	
	Seeds of Grasses	7.2	
	Cultivated Grains, etc.	15.4	
	Greens	10.3	
	Insects	23.3	
Southwest Texas-Grasslands Drought Conditions			Campbell-Kissock et al., 1985
Summer	Seeds of Forbs	3.5[d]	
	Seeds of Grasses	51.7	

TABLE 3-75
Diet Composition of Northern Bobwhites (*Colinus virginianus)*

Location	Prey Taxon	Percent Volume	Reference
	Seeds/Fruits of Woody Plants	9.7	
	Unidentified Seeds	4.6	
	Green Vegetation	4.8	
	Invertabrates	25.8	
Fall	Seeds of Forbs	19.0	
	Seeds of Grasses	42.9	
	Seeds/Fruits of Woody Plants	-	
	Unidentified Seeds	-	
	Green Vegetation	1.8	
	Invertabrates	36.2	
Winter	Seeds of Forbs	12.0	
	Seeds of Grasses	4.9	
	Seeds/Fruits of Woody Plants	1.4	
	Unidentified Seeds	2.3	
	Green Vegetation	72.4	
	Invertabrates	6.5	

[a]Not Stated.
[b] percent volume; crop and gizzard contents.
[c] percent dry volume; crop contents.
[d] percent wet volume; crop contents.

Food Consumption Rate

Koerth and Guthrey studied captive northern bobwhites maintaining an environment typical for Texas and using commercial game food with only 5 – 10 percent water content (1990). In their study, bobwhites consumed 0.093 ± 0.0032 SE g/g BW/day in the winter, 0.067 ± 0.0021 SE g/g BW/day in the spring, 0.079 ± 0.0061 SE g/g BW/day in the summer, and 0.072 ± 0.0017 SE g/g BW/day in the fall. Robel (1969) also studied bobwhites in Kansas and reported food consumption rates of 587 kcal/kg BW/day in winter, 657 kcal/kg BW/day in fall and 519 kcal/kg BW/day in spring. Robel used the average volume of crop content in shot birds, assuming a 1.5–hour retention period, 2.30 kcal/cm^3 for the contents and constant foraging throughout the day. These assumptions would most likely overestimate food consumption. Food ingestion can be calculated using Eq. 9 and a mean body weight of 0.175 kg (as calculated from Table 3-74 using adult birds). This estimate results in a value of 0.11 kg/kg BW/day. To determine the fresh weight food ingestion using Eq. 18 (0.20 kg/kg BW/day FW) a diet of 61.1 percent seeds, 11.3 percent fruits, and 20.3 percent invertebrates (Handley, 1931) with water contents of 9.3, 77, and 69 percent (Table 3-4) was assumed. (Note: If other body weight values are used, then the rates should be recalculated.)

Water Consumption Rate

In some areas, bobwhites apparently can acquire their daily water needs from dew, succulent plants, and insects (Stoddard, 1931); in more arid areas or in times of drought, however, northern bobwhite need surface water for drinking (Johnsgard, 1988a; Lehmann, 1984; Prasad and Guthery, 1986). Females need more water than males during the breeding season, and both sexes may require more water in the winter than in the summer when their diet is more restricted to seeds with low water content (Koerth and Guthery, 1990). Measurements on captive quail have indicated a daily water requirement of up to 13 percent of their body mass; however, water intake requirements for free-ranging birds may be higher, perhaps 14 to 21 percent of body mass per day (Koerth and Guthery, 1990). In the absence of adequate water, females may fail to reproduce (Koerth and Guthery, 1991).

Captive male bobwhites consumed 0.10 ± 0.023 SD g/g BW/day and captive female bobwhites consumed 0.13 ± 0.037 SD g/g BW/day in southern Texas during the summer (Koerth and Guthery, 1990). This compares to 0.11 and 0.11 L/kg BW/day for adult female and male bobwhite, respectively, which was calculated using Eq. 20 and a body weights from Roseberry and Kilmstra (1971). (Note: If other body weight values are used, then the rates should be recalculated.)

Soil Ingestion

No information was found concerning soil ingestion for bobwhite quail in the literature. However, Korschgen (1948) found that bobwhites consume little grit (just 3.4 percent of over 5, 000 crops examined). It is likely that hard seeds can replace grit as the grinding agent for northern bobwhite (Nestler, 1946).

Respiration Rate

No data concerning inhalation rates in bobwhite were available in the literature. Inhalation rates for both adult female and male bobwhite (0.61 m^3 air/kg BW/day) can be estimated using Eq. 22 and mean male and female body weight from Roseberry and Kilmstra (1971). (Note: If other body weight values are used, then the rates should be recalculated.)

Metabolism

Case (1982) estimated metabolic rates for non-breeding and laying adult females in Nebraska. Non-breeding females had a rate of 183.3 kcal/kg BW/day, while laying females had a rate of 243.9 kcal/kg BW/day. Basal rates can be estimated using the equation from Lasiewski and Dawson (1967) and free-living rates can be estimated using the equation from Nagy (1987). Basal rates were 125 and 129 kcal/kg BW/day for females and males, while free-living rates were 311 and 320 kcal/kg BW/day. Both calculations used summer body weights from Roseberry and Klimstra (1971). (Note: If other body weight values are used, then the rates should be recalculated.)

Habitat Requirements

During the breeding season, grasslands, idle fields, and pastures are the preferred nesting habitat, and bobwhite often nest in large clumps of grasses (Roseberry and Klimstra, 1984). Shade, open herbaceous cover, and green and growing vegetation are required for suitable nest sites (Lehmann, 1984). Bobwhites forage in areas with open vegetation, some bare ground, and light litter (Stoddard, 1931). Nearby dry powdery soils are important for dust bathing (Johnsgard, 1988a). Shrubby thickets up to 2 m high are used for cover during midday (Schroeder, 1985). Although their range is extensive, northern bobwhite reproduce poorly in the arid western portions of their range and during droughts elsewhere (Schroeder, 1985). During the winter, they require wooded cover with understory for daytime cover, preferably adjacent to open fields for foraging (Yoho and Dimmick, 1972). They tend to roost at night in more open habitats with short and sparse vegetation (Schroeder, 1985). In the more northern latitudes, cover and food can be limited during the winter (Rosene, 1969). Changes in land use, primarily the distribution of farms and farming methods, have eliminated large areas of bobwhite habitat in the last three decades (Brennan, 1991).

Home Range

In the breeding season, the bobwhite's home range includes foraging areas, cover, and the nest site and may encompass several hectares. Mated males and incubating females have the smallest spring and summer home ranges; bachelor males and post-nesting males and females have much larger foraging ranges. Crim and Seitz (1972) reported a mean home range size of 3.6 ha for adult bobwhites inhabiting a state game area in Iowa during the summer. Mated and unmated males in south Illinois (idle farms, woods, brush, cornfields) had summer home ranges of 7.6 $\pm$ 5.0 SD ha and 16.7 $\pm$ 9.5 ha, respectively (Urban, 1972). Nesting and post-nesting females in the same study had home ranges of 6.4 $\pm$ 4.0 and 15.6 $\pm$ 9.1 ha, respectively.

Bobwhite tend to use a portion of their home range more intensively than the remainder of the range (Urban, 1972). In the fall and winter, the range of each bobwhite covey must include adequate open foraging areas and cover, typically shrubby or woody thickets (Rosene, 1969). Each covey may utilize an area of several hectares, although as in summer, there tend to be activity centers where the quail spend most of their time (Yoho and Dimmick, 1972). In winter, the home range size of bobwhites was 6.8 $\pm$ 2.9 SD ha/covey in Tennessee woods and fields (Yoho and Dimmick, 1972). In contrast, Bartholomew (1967) reported a winter home range of bobwhites as 15.4 ha/covey (range, 12.1 – 18.6) in southern Illinois.

Population Density

Bobwhite density depends on food and cover availability and varies from year to year as well as from one location to another (Roseberry and Klimstra, 1984). Densities are highest at the end of the breeding season in the fall. In the southeast, densities may reach values as high as 7. 5 birds (adults and juveniles)/ha, although average values of 2 to 3 may be more common in these areas (Guthery, 1988; Lehmann, 1984; Smith et al., 1982). Winter and spring densities between 0.1 and 0.8 birds/ha have been recorded in the spring further north (Roseberry et al., 1979).

Population Dynamics/Survival

Bobwhites attempt to rear one or two broods per year (up to three in the south) (Bent, 1932; CKWRI, 1991; Stanford, 1972b). Bobwhite clutch sizes are generally smaller in more southerly populations (Roseberry and Klimstra, 1984) and smaller as the breeding season progresses in any given locale (Lehmann, 1984; Simpson, 1976). Predation is a major cause of nest loss; once hatched, chicks leave the nest immediately to follow both or one parent (Lehmann, 1984; Roseberry and Klimstra, 1984). Juveniles can survive without parental care after about 6 weeks of age (Lehmann, 1984). They reach maturity by 16 weeks of age in the laboratory although they continue to gain weight through about 20 weeks (Moore and Cain, 1975), and they may require 8 to 9 months to mature in the wild (Johnsgard, 1988a; Jones and Hughes, 1978). Adult mortality as well as juvenile mortality is high, with 70 to 85 percent of birds surviving less than 1 year (Brownie et al., 1985; Lehmann, 1984); thus, the bulk of the population turns over each year. In Florida, annual mortality is 52 percent for males and 56 percent for females (Pollock et al., 1989). This decrease may be due to the fact that the survey area was a no hunting zone. Longevitey has been reported in Texas as 10.6 years (Lehmann, 1984) and in Missouri as 8.5 years (Marsden and Baskett, 1958).

Reproduction/Breeding

Northern bobwhite build nests on the ground in open woodlands or in or around fields used for foraging. Most nests are constructed in grassy growth near open ground, often in areas with scattered shrubs and herbaceous growth (Klimstra and Roseberry, 1975; Stoddard, 1931). Both the male and female scrape out a saucer-shaped depression in the ground 2 to 6 cm deep and 10 to 12 cm across, lining it with dead grasses from the previous year's growth (Bent, 1932; Rosene, 1969). They lay large clutches, 12 to 30 eggs, which one or both parents incubate for approximately 23 days (Lehmann, 1984; Simpson, 1976). As a general rule, clutch size and nest success both decrease as the season progresses (Roseberry and Klimstra, 1984). Mean clutch size of nests in south Texas was 12.9 eggs (Lehmann, 1984) and 13.7 eggs for nests in Illinois (Roseberry and Klimstra, 1984). In southwest Georgia mean clutch size was 25 eggs in March with a mean of 20 birds fledging per successful nest and 9.4 eggs in April with a mean of 8.4 fledging (Simpson, 1976).

Behavior and Social Organization

Family units, consisting of both the male and female as well as the offspring, sometimes remain intact through the summer, but more often, one or both parents are lost to predation (some females leave their brood to the male and begin another), and other pairs or individual adults may adopt chicks from other broods (Lehmann, 1984). By fall, northern bobwhites of all ages gather in larger coveys for the fall and winter. The quail remain in coveys until the next spring, when they disperse as mating season begins (Lehmann, 1984; Roseberry and Klimstra, 1984). Coveys of northern bobwhite tend to average 10 to 12 or 15 birds (up to 30) (Johnsgard, 1988; Lehmann, 1984; Rosene, 1969). When roosting in winter, the birds in a covey form a small circle on the ground under a tree or in thick brush, with heads facing outward and their bodies closely packed to conserve heat.

The northern bobwhite is a year-round resident over its entire range but may disperse locally to a different cover type or altitude with the changing season (Lehmann, 1984). Most winter in wooded or brushy areas, returning to more open habitats in spring for the breeding season (Lehmann, 1984; Rosene, 1969). Populations nesting at higher elevations tend to move to lower ground where the winters are less severe (Stoddard, 1931). The more southerly populations may be more sedentary; in a study in Florida, northern bobwhite were found no further than 1 km from where they were banded, and 86 percent were found within 400 m from their banding site over a 1-to 5-year period (Smith et al., 1982).

Quail frequently dustbathe, although the reason for the behavior is debated. They scratch in dry dirt or dust, toss the dust up into their feathers, rub their head and sides in the dust, and then shake the dust from their plumage (Borchelt and Duncan, 1974). Experiments by Driver et al. (1991) indicate that ingestion of materials preened from feathers and direct dermal uptake can be significant exposure pathways for quail exposed to aerial application of pesticides. Dust bathing might, therefore, provide a significant exposure route for bobwhites using contaminated soils.

3.3.14 Spotted Sandpiper (*Actitis macularia*)[1]

The spotted sandpiper (*Actitis macularia*) is in the order Charadriiformes, family Scolopacidae. The family Scolopacidae includes numerous species of shorebirds, such as sandpipers, tattlers, knots, godwits, curlews, yellowlegs, willets, and dowitchers. Those known as sandpipers tend to be small with moderately long legs and bills. Most sandpipers forage on sandy beaches and mudflats; a few utilize upland areas. They feed almost exclusively on small invertebrates, either by probing into or gleaning from the substrate. Most species are highly migratory, breeding in arctic and subarctic regions and either wintering along the coasts or in southern latitudes and the southern hemisphere; therefore, many are only passage migrants throughout most of the United States. Scolapids range in size from the least sandpiper (11.5 cm bill tip to tail tip) to the long-billed curlew (48 cm).

Distribution

The spotted sandpiper (19 cm) is a very common summer resident of freshwater and saltwater bodies throughout most of the United States. Most winter in the neotropics.

Body Size and Weight

Females (approximately 50 g) are significantly larger than males (approximately 40 g) (Oring and Lank, 1986). Body weights for spotted sandpipers are presented in Table 3-76.

TABLE 3-76
Body Weights (g) for the Spotted Sandpiper (*Actitis macularia)*

Location	Sex	Mean	Reference
Minnesota Island	Female-Spring	47.1	Maxson & Oring, 1980
	Male-Spring	37.9	

Food Habits and Diet Composition

In coastal areas, spotted sandpipers search the beach and muddy edges of inlets and creeks, wading less frequently than most sandpipers; inland they feed along the shores of sandy

1 All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

ponds and all types of streams, sometimes straying into meadows, fields, and gardens in agricultural areas (Bent, 1929). Their diet is composed primarily of terrestrial and marine insects (Bent, 1929). While adult flying insects comprise the bulk of the diet, crustaceans, leeches, molluscs, small fish, and carrion also are eaten (Oring et al., 1983). Young feed themselves immediately after hatching, concentrating on small invertebrates (Oring and Lank, 1986). During insect outbreaks, sandpipers will forage in wooded areas near water, and they have been observed eating eggs and fish on occasion (Oring, pers. Obs).

Food Consumption Rate

There are no studies available that give specific food consumption rates for spotted sandpipers. An estimate of 0.18 kg/kg BW/day was obtained using Eq. 9 and a mean body weight of 0.0425 kg (calculated from the above table using adult birds). Equation 18 was used to calculate a fresh weight (0.46 kg/kg BW/day) assuming a diet of 100 percent invertebrates with a water content of 61 percent as listed for the beetle in Table 3-4. (Note: If other body weight differ values are used, then the rate should be recalculated.)

Water Consumption Rate

Although no data on water consumption rate in spotted sandpipers was available in the literature, it can be estimated. Using Eq. 20 and body weights from Maxson and Oring (1980) a water consumption rate of 0.16 L/Kg BW/day for females and 0.17 L/Kg BW/day for males is estimated. (Note: If other body weight differ values are used, then the rate should be recalculated.)

Soil Ingestion

Soil ingestion estimates could not be found in literature for the spotted sandpiper. However, rates of 7.3 to 30 percent of the diet have been reported for other sandpiper species (Beyer et al., 1994). These include the semipalmated sandpiper (30 percent of diet), the western sandpiper (18 percent of diet), the stilt sandpiper (17 percent of diet) , and the least sandpiper (7.3 percent of diet).

Respiration Rate

No data concerning inhalation rates among spotted sandpipers were available in the literature. Inhalation rates for females (0.83 m^3/kg BW/day) and males (0.87 m^3/kg BW/day) can be estimated using the Eq. 22 and body weights from Maxson and Oring (1980). (Note: If other body weight differ values are used, then the rate should be recalculated.)

Metabolism

Maxson and Oring (1980) estimated metabolic rates for males and females. Three stages were analyzed including pre-breeding (male and female), laying (female), incubating (male), and incubating (female), brooding (male). Pre-breeding ranges for females were from 404-787 kcal/kg BW/day while mean rate for males was 440 kcal/kg BW/day. While laying females had a range from 383 to 745. Incubating males had a mean rate of 303 kcal/kg BW/day. During incubation females had a mean rate of 368 and brooding males had a mean of 425 kcal/kg BW/day. Free living metabolic rates for males (460 kcal/kg BW/day) and females (436 kcal/kg BW/day) can also be estimated using equations from Nagy (1987) and body weights from Maxson and Oring (1980). (Note: If other body weight differ values are used, then the rate should be recalculated.)

Habitat Requirements

Spotted sandpipers breed along the edges of bodies of water, usually in open habitats, from the northern border of the boreal forest across North America, south to the central United States (Oring and Lank, 1986). They require open water for bathing and drinking, semi-open habitat for nesting, and dense vegetation for breeding (Bent, 1929; Oring et al., 1983).

Home Range

Although a variety of vegetation types are used, nests usually are placed in semi-open vegetation near the edge of a lake, river, or ocean (Oring et al., unpubl., as cited in Oring et al., 1983; McVey, pers. obs.). The suitability of nesting habitat varies from year to year in some locations due to levels of precipitation and predators (Oring et al., 1983). No information on home range size was available in the literature, but Maxson and Oring (1980) reported a territory size for spotted sandpipers of approximately 0.24 ha.

Population Density

Spotted sandpiper nesting densities have been studied well at only one location, on Little Pelican Island, Leech Lake, Minnesota. At this location, densities ranged from 4 to 13 females/ha and 7 to 20 males/ha over a 10-year period, depending on weather and other conditions (Oring et al., 1983).

Population Dynamics/Survival

Females may lay one to six clutches for different males over one season (Oring et al., 1984), averaging 1. 3 to 2. 7 mates per year (Oring et al., 1991b). Female mating and reproductive success increase with age, but male success does not (Oring et al., 1991b). Lifetime reproductive success is most affected by fledging success and longevity for both males and females (Oring et al., 1991a). Annual mortality rates in female sandpipers have been estimated at 31 percent in Minnesota, which is similar to the 30 percent annual mortality reported in males (Oring et al., 1983). Mean longevity in Minnesota as reported by Oring et al. (1983) is 3.7 years.

Reproduction/Breeding

The primary consideration for nesting sites is proximity to water, and spotted sandpipers have been known to build their ground nests in such diverse conditions as depressions in volcanic rock and strawberry patches (Bent, 1929). Spotted sandpipers are polyandrous (i. e., a single female lays eggs for multiple males), with males supplying most of the incubation and parental care (Oring, 1982). Thus reproduction is limited by the number of males present (Lank et al., 1985). Spotted sandpipers lay a determinate clutch of four eggs. Females may lay several clutches in a year, often a dozen eggs per season (Maxson and Oring, 1980). Egg laying begins between late May and early June in Minnesota (Lank et al., 1985), and males incubate after the third egg is laid (Oring et al., 1986). Females sometimes incubate and brood when another male is not available (Maxson and Oring, 1980). Parents brood small chicks and protect them with warning calls or by distracting or attacking predators (Oring and Lank, 1986).

Behavior and Social Organization

Spotted sandpipers generally migrate in small flocks or solitarily (National Geographic Society, 1987). They winter from southern United States to northern Chile, Argentina, and Uruguay (Oring and Lank, 1986), and breed across North America, north from Virginia and southern California (National Geographic Society, 1987). In the spring, females arrive at the breeding grounds earlier than males (in one study, by about 2 weeks; Oring and Lank, 1982). Lank et al. (1985) noted that migration in Minnesota began in late June and peaked in early to mid-July for females but didn't begin until early July for males.

These sandpipers are most often encountered singly but may form small flocks.

3.3.15 American Woodcock (*Scolopax minor*)[1]

American woodcock (*Scolopax minor*) belong to the order Charadriformes and family Scolopacidae. American woodcock and snipe are inland members of the sandpiper family that have a stocky build, long bill, and short legs. However, their habitats and diet are distinct. Woodcock inhabit primarily woodlands and abandoned fields, whereas snipe are found in association with bogs and freshwater wetlands. Both species use their long bills to probe the substrate for invertebrates. The woodcock and snipe are similar in length, although the female woodcock weighs almost twice as much as the female snipe.

Distribution

The American woodcock breeds from southern Canada to Louisiana throughout forested regions of the eastern half of North America. The highest breeding densities are found in the northern portion of this range, especially in the Great Lakes area of the United States, northern New England, and southern Canada (Gregg, 1984; Owen et al., 1977). Woodcock winter primarily in the southeastern United States and are year-round residents in some of these areas. Woodcock are important game animals over much of their range (Owen et al., 1977).

Body Size and Weight

Woodcock are large for sandpipers (28 cm bill tip to tail tip), and females weigh more than males (Keppie and Redmond, 1988). Most young are full grown by 5 to 6 weeks after hatching (Gregg, 1984). Body weights for American woodcocks from different locations throughout their range are presented in Table 3-77.

Food Habits and Diet Composition

Woodcocks feed primarily on invertebrates found in moist upland soils by probing the soil with their long prehensile-tipped bill (Owen et al., 1977; Sperry, 1940). Earthworms are the preferred diet, but when earthworms are not available, other soil invertebrates are consumed (Miller and Causey, 1985; Sperry, 1940; Stribling and Doerr, 1985). Some seeds and other plant matter may also be consumed (Sperry, 1940). Krohn (1970) found that during summer most feeding was done in wooded areas prior to entering fields at night, but other studies have indicated that a significant amount of food is acquired during nocturnal activities (Britt, 1971, as cited in Dunford and Owen, 1973). Dyer and Hamilton (1974) found that during the winter in southern Louisiana, woodcock exhibited three feeding periods:

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[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

TABLE 3-77
Body Weights (g) for the American Woodcock (Scolopax minor)

Location	Sex	Mean	Reference
Throughout Range	Male	176	Nelson & Martin, 1953
	Female	218	
Maine	Male-April	134.6±2.9	Dwyer et al., 1988
	Male-May	133.8±5.8	
	Male-June	151.2±9.5	
Massachusetts	Adult Male-Summer	145.9	
	Juvenile Male-Summer	140.4	
	Adult Female-Summer	182.9	
	Juvenile Female-Summer	168.8	
Minnesota	Adult Male-Fall	169	Marshall (unpublished)
	Juvenile Male-Fall	164	
	Adult Female-Fall	213	
	Juvenile Female-Fall	212	
Wisconsin	At Hatching	13.0	Gregg, 1984

early morning (0100 to 0500 hours) in the nocturnal habitat, midday (1000 to 1300 hours) in the diurnal habitat, and at dusk (1700 to 2100 hours) again in the nocturnal fields; earthworms and millipedes were consumed in both habitat types. The chicks leave the nest soon after hatching, but are dependent on the female for food for the first week after hatching (Gregg, 1984). Food preferences of American Woodcocks are summarized in Table 3-78.

TABLE 3-78
Diet Composition of American Woodcocks *(Scolopax minor)*

Location	Prey Taxon	Percent Volume	Reference
North America NS[a]	Earthworms	67.8[b]	Sperry, 1940
	Diptera	6.9	
	Coleoptera	6.2	
	Lepidoptera	3.3	
	Other Animals	5.3	
	Plants	10.5	
Maine-Fields	*Earthworms*	58[c]	Krohn, 1970

TABLE 3-78
Diet Composition of American Woodcocks *(Scolopax minor)*

Location	Prey Taxon	Percent Volume	Reference
	Beetle Larvae	10	
	Grit (Inorganic)	31	
	Other Organic	1	
N. Carolina-Soybean fields	Earthworms	99+[d]	Stribling & Doerr, 1985
	Other Invertebrates	<1	
Alabama- NS[a]	*Earthworms*	87[e]	Miller & Causey, 1985
	Coleoptera	11	
	Hymenoptera	2	

[a]Not Stated
[b] percent volume; stomach contents
[c] percent wet weight; mouth esophagus, stomach, & proventriculus contents
[d] percent wet weight; digestive tract
[e] percent volume; esophagus contents

Food Consumption Rate

Stickel et al. (1965) reported a mean food ingestion rate of 0.77 g/g BW/day (range, 0.11-1.43 g/g BW/day) in captive woodcocks eating an earthworm diet during the winter in Louisiana. Using Eq. 9 and a mean body weight of 0.169 kg (as calculated from Table 3-77 using adult birds) a food consumption rate of 0.11 kg/kg BW/day can be estimated. A fresh weight of 0.69 kg/kg BW/day can be calculated using Eq. 18. A diet of 100 percent earthworms was assumed (Stribling and Doerr, 1985) with a water content of 84 percent (Table 3-4). (Note: if using other body weight values, then the rate should be recalculated.)

Water Consumption Rate

No literature data were found concerning water consumption rates in woodcocks. However, most of the woodcocks' metabolic water needs are reportedly met by their food (Mendall and Aldous, 1943, as cited in Cade, 1985), although captive birds have been observed to drink (Sheldon, 1967). A water consumption rate of 0.1 L/kg BW/day can be estimated using Eq. 20 and summer body weights from Nelson and Martin (1953). (Note: If other body weight values are used, then the rate should be recalculated.)

Soil Ingestion

Soil ingestion was found to make up 10.4 percent of the American woodcock diet as reported in Beyer et al. (1994). This would be about 0.01 kg/kg Bw/day.

Respiration Rate

No data concerning inhalation rates in American woodcock were available in the literature. Inhalation rates of 0.50 m^3 air/kg BW/day for females and 0.74 m^3 air/kg BW/day for males can be estimated using Eq. 22 and summer body weights from Nelson and Martin (1953). (Note: If other body weight values are used, then the rate should be recalculated.)

Metabolism

Basal and free-living metabolic rates were reported by Rabe et al. (1983b) for female woodcocks in south Michigan. Rates were 115 and 315 kcal/kg BW/day, respectively. Estimated basal and free-living metabolic rates for both male and female woodcock can be calculated using equations from Lasiewski and Dawson (1967) and Nagy (1987) and summer body weights from Nelson and Martin (1953). Basal rates for males and females were 126 and 118 kcal/kg BW/day while free-living rates were 313 and 269 kcal/kg BW/day. (Note: If other body weight values are used, then the rate should be recalculated.)

Habitat Requirements

Woodcock inhabit both woodlands and abandoned fields, particularly those with rich and moderately to poorly drained loamy soils, which tend to support abundant earthworm populations (Cade, 1985; Owen and Galbraith, 1989; Rabe et al., 1983a). In the spring, males use early successional open areas and openings in woods, interspersed with low brush and grassy vegetation, for singing displays at dawn and dusk (Cade, 1985; Keppie and Redmond, 1985). Females nest in brushy areas of secondary growth woodlands near their feeding areas, often near the edge of the woodland or near a break in the forest canopy (Gregg, 1984). During the summer, both sexes use second growth hardwood or early successional mixed hardwood and conifer woodlands for diurnal cover (Cade, 1985). At night, they move into open pastures and early successional abandoned agricultural fields, including former male singing grounds, to roost (Cade, 1985; Dunford and Owen, 1973; Krohn, 1970). During the winter, woodcock use bottomland hardwood forests, hardwood thickets, and upland mixed hardwood and conifer forests during the day. At night, they use open areas to some degree, but also forested habitats (Cade, 1985). Diurnal habitat and nocturnal roosting fields need to be in close proximity to be useful for woodcock (Owen et al., 1977).

Home Range

The home range of woodcocks encompasses both diurnal cover areas and nocturnal roosting areas and varies in size depending on season and the distribution of feeding sites and suitable cover. During the day, movements are usually limited until dusk, when woodcock fly to nocturnal roost sites. Hudgins et al. (1985) and Gregg (1984) found spring and summer diurnal ranges to be only 1 to 10 percent of the total home range. Hudgins et al. (1985) reported a median home range for active males of 73.6 ha (range, 38.2-171.2 ha) in Pennsylvania. In contrast, inactive males had a median home range of just 3.1 ha (range, 0.3-6.0 ha). Gregg (1984) reported a home range of 32.4 $\pm$ 27.6 SD (range, 7-98 ha) for both males and females during the summer in Wisconsin, whereas adult females with their brood only used 4.5 ha. Movement on the nocturnal roost sites also is limited; however, during winter, woodcock are more likely to feed and move around at night (Bortner, pers. comm.). Singing males generally restrict their movements more than non-singing males, juveniles, and females (Owen et al., 1977). Median home range size for singing males in Pennsylvania was 10.5 ha (range, 4.6-24.1 ha; Hudgins et al., 1985).

Population Density

The annual singing-ground survey conducted by the United States and Canada provides information on the population trends of woodcock in the northern states and Canada during the breeding season (note from B. Bortner, U. S. Fish and Wildlife Service, Office of Migrating Bird Management, to Susan Norton, January 9, 1992). Gregg (1984) summarized results of several published singing-ground surveys and found estimates to vary from 1.7 male singing grounds per 100 ha in Minnesota (Godfrey, 1974, cited in Gregg, 1984) to 10.4 male singing grounds per 100 ha in Maine (Mendall and Aldous, 1943, cited in Gregg, 1984). Although this method is appropriate for assessing population trends, flushing surveys, telemetry, and mark-recapture are better methods for estimating woodcock densities because there are variable numbers of females and non-singing males associated with active singing grounds (Dilworth, Krohn, Riffenberger, and Whitcomb pers. comm., cited by Owen et al., 1977). For example, Dwyer et al. (1988) found 2. 2 singing males per 100 ha in a wildlife refuge in Maine, but with mark-recapture techniques, they found yearly summer densities of 19 to 25 birds per 100 ha in the same area. Population densities in North Carolina agricultural areas recorded during the winter by Connors and Doerr (1982) include 3.38 birds/ha in untilled soy stubble, 0.2 birds/ha in untilled corn stubble, and 0.034 birds/ha in rebedded corn fields. Coon et al. (1982) reported a density of 0.21 nests/ha during the spring in Pennsylvania. During the summer in Maine, Dwyer et al. (1988) reported densities of 0.035 birds/ha for males, 0.056 birds/ha for females, 0.125 birds/ha for juveniles and 0.223 birds/ha for all birds.

Population Dynamics/Survival

Woodcocks attempt to raise only a single brood in a given year but may renest if the initial clutch is destroyed (McAuley et al., 1990; Sheldon, 1967). In 12 years of study in Wisconsin, Gregg (1984) found 42 percent of all nests to be lost to predators and another 11 percent lost to other causes. Survival of juveniles in their first year ranges from 20 to 40 percent, and survival of adults ranges from 35 to 40 percent for males to approximately 40 to 50 percent for females (Dwyer and Nichols, 1982; Krohn et al., 1974). Derleth and Sepik (1990) found high adult survival rates (0.88 to 0.90 for both sexes) between June and October in Maine, indicating that adult mortality may occur primarily in the winter and early spring. They found lower summer survival rates for young woodcock between fledging and migration than for adults during the same months, with most losses of young attributed to predation.

Reproduction/Breeding

From their arrival in the spring, male woodcock perform daily courtship flights at dawn and at dusk, defending a site on the singing grounds in order to attract females for mating (Owen et al., 1977; Gregg, 1984). Often several males display on a single singing ground, with each defending his own section of the area. Females construct their nests on the ground, usually at the base of a tree or shrub located in a brushy area adjacent to an opening or male singing ground (Gregg and Hale, 1977; McAuley et al., 1990; Owen et al., 1977). Generally, one clutch per year is produced, but renesting may occur if initial clutch is lost (McAuley et al., 1990). Mean clutch size throughout their range and across various habitats was 4 eggs (range, 3-5 eggs; Bent, 1927). McAuley et al., (1990) reported a clutch size of 3.8 $\pm$ 0.42 SD eggs in first clutches and 3.0 $\pm$ 0.67 SD in second clutches of females nesting in Maine. Females are responsible for all of the incubation and care of their brood (Trippensee, 1948). Incubation lasts

19-20 days (Mendall and Aldous, 1943; Pettingill, 1936). The young leave the nest soon after hatching and can sustain flight by approximately 18 days of age (Gregg, 1984).

Behavior and Social Organization

Fall migration begins in late September and continues through December, often following the first heavy frost (Sheldon, 1967). The migration may take 4 to 6 weeks (Sheldon, 1967). Some woodcock winter in the south Atlantic region, while those that breed west of the Appalachian Mountains winter in Louisiana and other Gulf States (Martin et al., 1969, as cited in Owen et al., 1977). Woodcock are early spring migrants, leaving their wintering grounds in February and arriving on their northern breeding grounds in late March to early April (Gregg, 1984; Sheldon, 1967; Owen et al., 1977). Dates of woodcock arrival at their breeding grounds vary from year to year depending on the timing of snowmelt (Gregg, 1984). Sheldon (1967) summarizes spring and fall migration dates by States from numerous studies. Birds have been reported by Connors and Doerr (1982) as leaving North Carolina beginning in mid-February and ending in early March. Gregg (1984) reported woodcock arriving in the northern range beginning in March and peaking in April. Fall migration into North Carolina was recorded starting in October and ending in December (Sheldon, 1967) while fall migration leaving Canada was noted to start in late September and end in mid-December (Owen et al., 1977).

3.3.16 Herring Gull (*Larus argentatus*)[1]

Herring gulls (*Larus argentatus*) are in the order Charadriiformes, family Laridae. Gulls are medium-to large-sized sea birds with long pointed wings, a stout, slightly hooked bill, and webbed feet. They are abundant in temperate coastal areas and throughout the Great Lakes. Although gulls may feed from garbage dumps and landfills, most take natural prey. Gulls nest primarily in colonies, although some of the larger species also nest solitarily. Many populations migrate annually between breeding and wintering areas. North American gull species range in size from onaparte's gull (33 cm bill tip to tail tip) to the great black-backed gull (76 cm). Along the Pacific coast, the similar-sized western gull (*L. occidentalis*) is the ecological equivalent of the herring gull. Both species take primarily natural foods, especially fish, although some individuals of both species forage around fishing operations and landfills (Pierotti, 1981, 1987; Pierotti and Annett, 1987).

Distribution

The herring gull (64 cm) has the largest range of any North American gull, from Newfoundland south to the Chesapeake Bay along the north Atlantic and west throughout the Great Lakes into Alaska.

Body Size and Weight

Adult females (800 to 1,000 g) are significantly smaller than males (1,000 to 1,300 g) in both the herring gull (Greig et al., 1985) and the western gull (Pierotti, 1981). Chicks grow from their hatching weight of about 60 to 70 g to 800 to 900 g within 30 to 40 days, after which time their weight stabilizes (Dunn and Brisbin, 1980; Norstrom et al., 1986; Pierotti, 1982). Norstrom et al. (1986) fitted chick growth rates to the Gompertz equation as follows:

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[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

$BW = 997\ e^{-e(-0.088(t-14.8))}$ for females,

and

$BW = 1193\ e^{-e(-0.075(t-16.3))}$ for males,

where , BW equals body weight in grams and t equals days after hatching.

Adults show seasonal variation in body weight (Coulson et al., 1983; Norstrom et al., 1986). Body weights for herring gulls from different locations throughout their range are presented in Table 3-79.

TABLE 3-79
Body Weights (g) for the Herring Gull (*Larus argentatus)*

Location	Sex	Mean	Reference
Lake Huron	Female-Spring	951± 88	Norstrom et al., 1986
	Male-Spring	1184 ± 116	
Newfoundland	Female-Summer	999 ± 90	Threlfall & Jewer, 1978
	Male-Summer	1232 ± 107	
Maine	At Hatching	65	Dunn & Brisbin, 1980
	10 days old	230	
	20 days old	590	
	30 days old	810	
Newfoundland-Rock Island	30 days old	964 ± 77	Pierottti, 1982
Newfoundland-Grassy Island	30 days old	818 ± 99	Pierottti, 1982

Food Habits and Diet Composition

Gulls feed on a variety of foods depending on availability, including fish, squid, crustacea, molluscs, worms, insects, small mammals and birds, duck and gull eggs and chicks, and garbage (Bourget, 1973; Burger, 1979a; Fox et al., 1990; Pierotti and Annett, 1987). Gulls forage on open water by aerial dipping and shallow diving around concentrations of prey. At sea, such concentrations often are associated with whales or dolphins, other seabirds, or fishing boats (McCleery and Sibly, 1986; Pierotti, 1988). In the Great Lakes, concentrations of species such as alewife occur seasonally (e. g., when spawning) (Fox et al., 1990). Gulls also forage by stealing food from other birds and by scavenging around human refuse sites (e. g., garbage dumps, fish plants, docks, and seaside parks) (Burger and Gochfeld, 1981; 1983; Chapman and Parker, 1985). Individual pairs of gulls may specialize predominantly on a single type of food; for example, three quarters of a population of herring gulls in Newfoundland were found to specialize either on blue mussels, garbage, or adults of Leach's storm-petrel, with 60 percent of the specialists concentrating on mussels between 0.5 and 3 cm in length (Pierotti and Annett, 1987; 1991). Diet choices may change with the age and experience of adult birds as well as with availability of prey (Pierotti and

Annett, 1987; 1991). Females take smaller prey and feed less on garbage than do males (Pierotti, 1981; Greig et al., 1985). For example, Fox et al. (1990) found females to feed more on smelt (100 to 250 mm) and males more on alewife (250 to 300 mm) in the Great Lakes region. Adult gulls sometimes attack and eat chicks of neighboring gulls or other species of seabird (Brown, 1967; Schoen and Morris, 1984). Juveniles up to 3 years of age forage less efficiently than adults (Greig et al., 1983; MacLean, 1986; Verbeek, 1977). In the Great Lakes, herring gulls' high consumption of alewife during their spawn may result in high exposures of the gulls to lipophilic contaminants that biomagnify (Fox et al., 1990). Food preferences herring gulls are summarized in Table 3-80.

TABLE 3-80
Diet Composition of Herring Gulls (*Larus argentatus)*

Location	Prey Taxon	Percent Volume	Reference
Newfoundland-Island			Haycock & Threlfall, 1975
Summer	*Mytiluse edulis*	30.9[a]	
Mid-May/Mid-June			
	Sea Urchin	5.8	
	Fish	11.4	
	Oceanodroma leuchorhoa	22.4	
	Fratercula arctica - Adults	5.8	
	Fratercula, Uria - Chicks	0.0	
	Larus Spp.- Eggs	3.1	
	Vaccinum angustifolium	-	
	Gadus morhua Offal	12.4	
	Assorted Refuse	5.8	
Summer	*Mytilus edulis*	0.9	
Mid-June/Mid-July			
	Sea Urchin	0.0	
	Fish	71.1	
	Oceanodroma leuchorhoa	7.0	
	Fratercula arctica - Adults	0.0	
	Fratercula, Uria - Chicks	3.5	
	Larus Spp.- Eggs	0.9	
	Vaccinum angustifolium	-	
	Gadus morhua Offal	1.7	
	Assorted Refuse	0.9	
Summer	*MytiluseEdulis*	9.1	

TABLE 3-80
Diet Composition of Herring Gulls (*Larus argentatus)*

Location	Prey Taxon	Percent Volume	Reference
Mid-July/Mid-Aug			
	Sea Urchin	4.5	
	Fish	18.9	
	Oceanodroma leuchorhoa	15.9	
	Fratercula arctica - Adults	1.5	
	Fratercula, Uria - Chicks	9.1	
	Larus spp.- Eggs	0.8	
	Vaccinum angustifolium	9.9	
	Gadus morhua Offal	14.4	
	Assorted Refuse	6.8	
Lake Ontario			Fox et al., 1990
Summer 1978	American Smelt	46.1[b]	
	Alewife	23.1	
	Other Fish	20.5	
	Birds	2.6	
	Voles	2.6	
	Insects & Refuse	12.8	
Summer 1979	American Smelt	18.4	
	Alewife	73.7	
	Other Fish	0	
	Birds	2.6	
	Voles	2.6	
	Insects & Refuse	0	
Summer 1980	American Smelt	61.2	
	Alewife	16.7	
	Other Fish	3.4	
	Birds	13.8	
	Voles	3.4	
	Insects & Refuse	3.4	
Summer 1981	American Smelt	57.8	
	Alewife	23.4	
	Other Fish	3.1	

TABLE 3-80
Diet Composition of Herring Gulls (*Larus argentatus)*

Location	Prey Taxon	Percent Volume	Reference
	Birds	6.2	
	Voles	9.4	
	Insects & Refuse	0	
Great Lakes			Fox et al., 1990
Lake Ontario	Fish	91.8[c]	
	Insects	5.5	
	Offal, Garbage	0.5	
	Gull Chicks	2.2	
	Adult Birds	1.6	
	Amphibians	0.5	
	Earthworms	2.2	
	Crayfish	0	
Lake Erie	Fish	94.1	
	Insects	5.9	
	Offal, Garbage	2.9	
	Gull Chicks	0	
	Adult Birds	0	
	Amphibians	0	
	Earthworms	0	
	Crayfish	0	
Lake Huron	Fish	75.8	
	Insects	5.6	
	Offal, Garbage	13.6	
	Gull Chicks	1.0	
	Adult Birds	1.0	
	Amphibians	0	
	Earthworms	11.6	
	Crayfish	0.5	
Lake Superior	Fish	38.6	
	Insects	42.1	

TABLE 3-80
Diet Composition of Herring Gulls (*Larus argentatus*)

Location	Prey Taxon	Percent Volume	Reference
	Offal, Garbage	21.0	
	Gull Chicks	0	
	Adult Birds	3.5	
	Amphibians	0	
	Earthworms	1.7	
	Crayfish	0	
CA, FL, NY, NJ, TX - Coastal	Snails	3[d]	Burger, 1988
	Crabs	14	
	Garbage	27	
	Offal	5	
	Worms	23	
	Other Inverts.	28	
	Fish	unknown	

[a] percent occurrence in regurgitations and pellets
[b] percent occurrence in regurgitations from and stomach contents of incubating adults
[c] percent occurrence in boli regurgitated by chicks
[d] percent of gulls feeding on items; offshore feeding on fish was not included in observations

Food Consumption Rate

Food ingestion of herring gulls in Newfoundland was estimated by Pierotti and Annett (1991). Birds on a diet of mussels were estimated to have an ingestion rate of 0.2 g/g BW/day for males and 0.21 g/g BW/day for males. Those birds on a diet of garbage averaged slightly lower with an ingestion rate of 0.19 and 0.18 g/g BW/day for females and males, respectively. Using Eq. 9 and a mean body weight of 1.1 kg (as calculated from the above table using adult birds) an estimate of 0.056 kg/kg BW/day was obtained. Equation 18 was used to calculate a fresh weight (0.23 kg/kg BW/day) and a diet of 91.8 percent fish, 5.5 percent insects, 3.8 percent birds, 0.5 percent amphibian, and 2.2 percent earthworms (Fox et al., 1990) was used. Respective water contents as extracted from Table 3-4 are 75 percent, 68 percent, 68 percent, 85 percent, and 84 percent. (Note: If other body weight values are used, then the rate should be recalculated.)

Water Consumption Rate

No literature data were found describing water ingestion by herring gulls. Using Eq. 20 and assuming a body weight of 1.1 kg, water ingestion is estimated to average 0.057 L/kg BW/day (Note: If other body weight values are used, then the rate should be recalculated.)

Soil Ingestion

No soil ingestion information was found in the literature. However, herring gulls are primarily piscivorous and soil ingestion is expected to be negligible.

Respiration Rate

No data concerning inhalation rates in herring gulls was available in the literature. Inhalation rates can be estimated using Eq. 22 and body weights from Threlfall and Jewer (1978). Estimates were 0.39 m^3/kg BW/day for males and 0.41 m^3/kg BW/day for females. (Note: If other body weight values are used, then the rate should be recalculated.)

Metabolism

Norstrom et al. (1986) have estimated an annual energy budget for free-living female herring gulls that breed in the Great Lakes and an annual energy budget for free-living juvenile herring gulls in the Great Lakes in their first year. Between September and March, the nonbreeding season, they estimate that adult females require 250 to 260 kcal/day. Following a dip in energy requirements to 210 kcal/day when the male feeds the female during courtship, the female's needs increase to peak at 280 kcal/day for egg production, then falls to approximately 210 kcal/day during incubation. The energy required to forage for food for the chicks is substantial, rising through July to peak in August at 310 to 320 kcal/day, then declining again until September when feeding chicks has ceased. These estimates compare well with those derived from Nagy's (1987) equation to estimate free-living metabolic rates for seabirds, except that the energy peaks required to produce eggs and to feed chicks are not included in Nagy's model. Using equations in Nagy (1987), free living metabolic rate of 233 kcal/kg BW/day for males and 248 kcal/kg BW/day for females were estimated. Basal rates were also estimated for males (86 kcal/kg BW/day) and females (91 kcal/kg BW/day). Lustick et al.(1978) published a standard metabolic rate for herring gulls of 99 kcal/kg BW/day. Body weights used were from Threlfall and Jewer (1978). Readers interested in the metabolic rates of first-year herring gulls are referred to Norstrom et al. (1986). Ellis (1984) provides an overview of seabird energetics and additional discussion of approaches and models for estimating metabolic rates of free-ranging seabirds.

Habitat Requirements

Nesting colonies of herring gulls along the northeastern coast of the United States are found primarily on sandy or rocky offshore or barrier beach islands (Kadlec and Drury, 1968). In the Great Lakes, they are found on the more remote, secluded, and protected islands and shorelines of the lakes and their connecting rivers (Weseloh, 1989). Smaller colonies or isolated pairs also can be found in coastal marshes (Burger, 1980a), peninsulas, or cliffs along seacoasts, lakes, and rivers (Weseloh, 1989), and occasionally in inland areas or on buildings or piers (Harris, 1964). Gulls are the most abundant seabirds offshore from fall through spring, and are only found predominantly inshore during the breeding season in late spring and summer (Powers, 1983; Pierotti, 1988). Gulls forage predominantly offshore, within 1 to 5 km of the coast (Pierotti, 1988). In all seasons the number of birds feeding at sea outnumber those feeding inshore (data from Powers, 1983; Pierotti, pers. comm.). Inshore, herring gulls forage primarily in intertidal zones but also search for food in wet fields, around lakes, bays, and rock jetties, and at landfills in some areas (Burger, 1988). In Florida, herring gull presence at landfills is restricted to the winter months (December through April) and may consist primarily of first-year birds that migrated from more northerly populations (e. g., from the Great Lakes) (Patton, 1988).

Home Range

During the breeding season, herring gulls defend a territory of several tens of square meters around the immediate vicinity of the nest (Burger, 1980b). Their daily foraging range depends on the availability of prey and on the foraging strategy, age, and sex of the gull. Using radiotelemetry on gulls in the Great Lakes, Morris and Black (1980) demonstrated that some parents with chicks forage at specific locations within 1 km of the colony whereas other parents make extended flights to destinations across a lake more than 30 km away. Similarly, gulls that feed at sea may range tens of kilometers from their nest whereas gulls from the same colony feeding in the intertidal zone may travel less than 1 km (Pierotti and Annett, 1987; 1991). Males typically range farther than females and take larger prey items (Pierotti and Annett, 1987; 1991). At sea during the nonbreeding season, gulls may range hundreds of kilometers during a day, and Pierotti (pers. comm.) reported a mean foraging radius of 10 to 15 km for adult males and 5 to 10 km for adult females.

Population Density

As described above, population density is determined by available nesting space, size of the breeding population, and quality of habitat. Small islands with good feeding areas nearby can have several hundred nests per hectare (Kadlec, 1971; Parsons, 1976b; Pierotti, 1982). In poor quality habitat, some pairs nest solitarily without another nest for several kilometers (Weseloh, 1989). Population densities on coastal islands in Massachusetts were 227 nests/ha during the summer (Kadlec, 1971) whereas populations on rocky terrain on islands in Newfoundland had densities of 217 nest/ha compared to 75 nest/ha on grassy slopes (Pierotti, 1982).

Population Dynamics/Survival

Herring gulls and western gulls usually do not begin breeding until at least 4 years of age for males and 5 years of age for females (Burger, 1988; Pierotti, 1981; Pierotti, pers. comm.). Kadlec and Drury (1968) suggest that in a given year, 15 to 30 percent of adults of breeding age do not breed. Most breeding females produce three-egg clutches, but individuals in poor condition may lay only one or two eggs (Parsons, 1976a; Pierotti, 1982; Pierotti and Annett, 1987; 1991). Herring gulls will lay replacement eggs if all or a portion of their original clutch is destroyed (Parsons, 1976a). Hatching success appears to be influenced by female diet, with garbage specialists hatching a smaller percentage of eggs than fish or intertidal (mussel) specialists (Pierotti and Annett, 1987, 1990, 1991). Predation, often by gulls of the same or other species, also contributes to egg losses (Paynter, 1949; Harris, 1964; Davis, 1975). Many herring gull chicks that hatch die before fledging, most within the first 5 days after hatching (Harris, 1964; Kadlec et al., 1969; Brown, 1967). Adult mortality is low (around 10 percent per year), and some birds may live up to 20 years (Brown, 1967; Kadlec and Drury, 1968). Subadult birds exhibit higher mortality (20 to 30 percent per year) (Kadlec and Drury, 1968; Chabrzyk and Coulson, 1976). Herring gulls have been known to survive up to 30 years (Pierotti, pers. comm.).

The increase in number of herring gulls in this century has been attributed to the increasing abundance of year-round food supplies found in landfills (Drury, 1965; Harris, 1970); however, birds specializing on garbage have such low reproductive success that they cannot replace themselves in the population (Pierotti and Annett, 1987, 1991). An alternative explanation of the species' expansion is that cessation of taking of gulls by the feather industry in the late 1800's has allowed gull numbers to return to pre-exploitation levels (Graham, 1975).

Reproduction/Breeding

Gulls nest primarily in colonies on offshore islands, and nest density is strongly affected by population size (Pierotti, 1981; 1982; 1987). Typically, males arrive at the breeding grounds first and establish territories. Both sexes build the nest of vegetation on the ground in areas that are sheltered from wind but may be exposed to the sun (Pierotti, 1981; 1982). Males feed females for 10 to 15 days prior to the start of egg laying (Pierotti, 1981). From the laying of the first egg until the chicks are 3 to 4 weeks old, one or both parents will be present at all times (Tinbergen, 1960). Mean clutch size is about 2 (Burger, 1979b; Nisbet and Drury, 1984; Hunt, 1972; Meathrel et al., 1987) with one clutch per year unless the initial clutch is lost (Burger, 1979a; Bourget, 1973). Mean number of fledglings per successful nest was 1.8 along the coast of New Jersey (Burger and Shisler, 1980). Males perform most territorial defense, females perform most incubation, and both parents feed the chicks until they are at least 6 to 7 weeks old (Burger, 1981; Pierotti, 1981; Tinbergen, 1960). All gulls are strongly monogamous; pair bonds can persist for 10 or more years and usually only are terminated by the death of a mate or failure to reproduce successfully (Tinbergen, 1960). Males may be promiscuous in populations with more females than males (Pierotti, 1981). Herring gull colonies often are found in association with colonies of other species, including other gulls (Bourget, 1973; Brown, 1967). In some nesting colonies, gulls attack chicks of neighboring gulls and other species (Brown, 1967; Schoen and Morris, 1984).

Behavior and Social Organization

Herring gull populations along the northeast coast of North America tend to be migratory, while adult herring gulls of the Great Lakes are year-round residents. Along the western North Atlantic, most herring gulls arrive on their breeding grounds between late February and late April. They remain until late August or early September when they leave for their wintering grounds along the Atlantic and Gulf coasts or well offshore (Burger, 1982; Pierotti, 1988). Adult and older subadult herring gulls in the Great Lakes area are essentially nonmigratory (Mineau et al., 1984; Weseloh et al., 1990). Thus, in contrast to other fish-eating birds in the Great Lakes system that migrate south in the winter, herring gulls are exposed to any contaminants that may be in Great Lakes' fish throughout the year (Mineau et al., 1984). Postbreeding dispersal away from breeding colonies begins in late July and ends in August, with all ages traveling short distances. Great Lakes herring gulls less than a year old usually migrate to the Gulf or Atlantic coast (Smith, 1959; Mineau et al., 1984), traveling along river systems and the coast (Moore, 1976). In northwestern Atlantic populations spring migration begins in February and ends in late April with fall migration starting in August and ending in September (Burger, 1982).

3.3.17 Mourning Dove (*Zenaida macroura*)[3]

The mourning dove is in the order Columbiformes, family Columbidae. It is among the most widespread terrestrial bird endemic to North and Middle America as well as the leading game bird in North America. Both population and geographic distribution have increased since the time of European Settlement on the continent (Mirarchi and Baskett, 1994).

Distribution

Z. macroura occupies parts of southern Canada, most of the continental United States and parts of temperate Mexico and lives in both rural and urban areas. There are two principle subspecies, the *Z. m. carolinensis* and the *Z. m. marginella* (Mirarchi and Baskett, 1994).

Body Size and Weight

The mourning dove is a streamlined, mid-sized columbid with a small head and long pointed tail. Coloring ranges from grayish blue to grayish brown above with buffy coloring below. Males average 26.5 to 34 cm in length while females range from 22.5 to 31 cm in length (Mariarchi and Baskett, 1994). Males are heavier than females while the eastern race (*Z. m. carolinensis*) is heavier than the western race (*Z. m. marginella*). The average weight for males is 130 g for the *Z. m. carolinensis* and 116 g for the *Z. m. marginella*. Females average 123 and 108 g, respectively (Mirarchi, 1993b).

TABLE 3-81
Body Weights (g) for the Mourning Dove (*Zenaida macroura*)

Location	Sex	N	Mean	Reference
New Mexico (summer)	Female (adult)	6	99.3	Griffing et al., 1977
	Male (adult)	13	111.4	
	Male (adult)			
New Mexico (winter)	Female (adult)	149	114.6	
			112.7	
Lab	Female (adult)	7	130.2	Ivacic and Labisky, 1973
	Male (adult)	3	143.9	
	Female (juvenile)	7	128.9	
	Male (juvenile)	3	136.8	
Virginia	Female (juvenile)	5	114.3	Mirarchi et al., 1980

Food Habits and Diet Composition

The diet of mourning doves consists mainly of seeds. Incidental ingestion of animal matter, mainly snails, and green forage may occur. Agricultural cereal grains such as corn, wheat, grain sorghum, millet, buckwheat and peanuts serve as the major food items if available.

[3] New species accounts compiled for ARAMS.

Other food items include herbaceous plants found in early successional stages including grasses, spurges, crotons, goosefoots, purslanes, and smartweeds (Lewis, 1993).

TABLE 3-82
Diet Composition of the Mourning Dove (*Zenaida macroura*)

Location	Prey Taxon	Percent Volume	Reference
New Mexico (Fall-winter)	Seeds	99.9	Davis, 1974
	Green vegetation	0.1	
New Mexico (Summer)	Seeds	96.1	Davis, 1974
	Green vegetation	1.1	
	Insects	2.8	
North Dakota (occurrence % by weight)	Green foxtail	39.8	Schmid, 1965
	Yellow foxtail	21.4	
	Wheat	19.6	
	Black bindwood	5.1	
	Maize	4.7	
	Proso millet	3	
	Flax	4	
	Field mustard	1.6	
	Lamb's quarters	1.2	

Food Consumption Rate

A range for the food consumption rate of 7-17 g/day was estimated for the mourning dove (Hanson and Kossack, 1957a). In general, daily food intake equals about 16 percent of the body mass though it fluctuates during different seasons (Taber, 1928). Using Eq. 9 and assuming a body weight of 0.118 kg (as calculated from the above table using adult weights) a food consumption rate of 0.12 kg/kg BW/day can be estimated. A fresh weight of 0.14 kg/kg BW/day can be calculated using Eq. 18 and assuming a diet of 96.1 percent seeds, 1.1 percent green vegetation, and 2.8 percent insects (Davis, 1974) with respective water contents of 9.3, 85, and 61 percent (Table 3-4). (Note: If other body weight values are used, then the rate should be recalculated.)

Water Consumption Rate

The minimum water ration required to maintain body mass is 2.8 percent of body mass/day (MacMillen, 1962). While seawater is not used as a drinking source, saline sources up to 0.15 molar saltwater are used (Bartholomew and MacMillan, 1960). One study found daily *ad libitum* water consumption by captive birds to be 6.9 $\pm$ 0.9 percent of body weight per day (MacMillen, 1962). Using Eq. 20 and mean body weight of 0.118 kg, a water consumption rate of 0.12 L/kg BW/day can be calculated. (Note: If other body weight values are used, then the rate should be recalculated.)

Soil Ingestion

No information on soil ingestion was found in the literature. Beyer et al. (1994) reported soil ingestion of 9.3 percent of diet for wild turkeys. Because mourning doves also forage on the ground, it is assumed that mourning doves would have a comparable soil ingestion to that of wild turkeys. However, it should be noted that 9.3 percent is likely an upperbound value and therefore, its use would be very conservative.

Respiration Rate

No information was found in the literature on inhalation rates. An inhalation rate of 0.67 m^3/kg BW/day is estimated using Eq. 22 and a mean body weight of 0.118 kg. (Note: If other body weight values are used, then the rate should be recalculated.)

Metabolism

Immature birds generally have a higher metabolism than adults, with females having a higher metabolism than males (Ivacic and Labisky, 1973). Metabolic expenditures are dependent on ambient temperature as opposed to light: dark ratios. Metabolic rate, body temperature, and heart rate appear to drop at temperatures below 30 °C (Mirarchi, 1993a). In one study mean oxygen consumption during the light period at 10 °C was 1.11 □ 0.29 SD mL O_2/g BW/h for juvenile and adult males (n = 6). The rate for juvenile and adult females was 1.14 mL O_2/g BW/h (Ivacic and Labisky, 1973).

Habitat Requirements

Z. macroura are very adaptable and consequently live in a variety of ecological habitats including urban and rural locations (Mararchi and Baskett, 1994). Generally they avoid heavily forested areas and prefer more open woodland. They nest in open areas such as edges, between forest and prairie biomes, and agricultural areas (Tomlimson et al., 1994).

Home Range

In adult mourning doves from Missouri, males were found from 0.8-7.8 km from the nest daily (Sayre et al, 1980). Females were noted as far as 5.4 km from the nest. In Idaho, the average distance that adults fed from watering sites was 3.1 km. The average distance traveled from nesting sites to feeding or loafing sites was 3.7 km. The farthest a dove was reported to travel was 6 km (Howe and Flake, 1988).

Population Density

The mourning dove is ranked among the top ten most abundant birds in North and Middle America (Mirarchi and Baskett, 1994) and fall estimates as of the late 1980s indicated a population of 475 million birds. However, recent call-count surveys suggest significant declines between 1966 and 1998 in the Eastern, Central, and Western Management Units of the United States (Dolton and Smith, 1998). Population numbers usually peak around September and October with increases beginning in the spring and lasting through late summer (Tomlinson et al., 1994).

Various population densities have been reported for mourning doves within the United States. Densities of 1.33 pairs/ha (3.3 pairs/acre) were reported for mourning doves nesting in Georgia (Hopkins and Odum, 1953), while only 0.8 pairs/ha (2.01 pairs/acre) were nesting in Texas (Swank, 1955). Approximately 0.5 pairs/ha (250 pairs/220 acres) and 0.6 pairs/ha (330 pairs/220 acres) in 1938 and 1939 were observed nesting in Iowa (McClure, 1942). In North Dakota, where the native grasslands have been greatly altered by human activities, an average of 0.035 pairs/ha (9.08 pairs/mi^2) were observed in 1967 (Stewart and Kantrud, 1972). Similarly low densities (0.02 nests/ha) were reported for ground-nesting mourning doves in a cold desert ecosystem in Idaho (Howe and Flake, 1989).

Population Dynamics/Survival

Average life span for immature mourning doves is 1 year and 1.5 years for adults but the longevity record reported by the federal Bird Banding Laboratory (2000) for a wild mourning dove is 31 years 4 months. Unweighted mean annual survival rate (percent) of adult males in selected hunting states was 38.9 $\pm$ 1.3 and 37.4 + 1.8 for adult females (Martin and Sauer, 1993). For combined non-hunting states, the mean adult survival rate was 50.0 $\pm$ 2.9 (Mirarchi and Baskett, 1994).

At the local level, Schulz et al. (1996) radiomarked 315 mourning doves from 1990 to 1991 at two wildlife areas in Missouri to determine spring/summer survival. The overall survival estimate calculated using Kaplan-Meier Staggered Entry Survival Analysis was 0.716 with a range of 0.624 to 0.819 from 1990 to 1991 at the two sites. This is greater survival than annual survival rates estimated for the entire Western Management Unit (0.524 for adults). Based on this information, Schulz et al. (1996) suggested that spring/summer mortality may not be a major factor in mourning dove population declines.

Reproduction/Breeding

Mourning doves breed as far north as southern Canada, but primarily breed throughout the United States and south into Mexico, Bermuda, the Bahamas, the Greater Antilles, and into some parts of Central America (Dolton and Smith, 1998). Although the main breeding period is from April to September, breeding can begin in March and extend to October. In fact, breeding has been found to occur during the entire year along the Gulf Coast (Peters, 1961). Both male and female morning doves are capable of breeding within the first 6 to 12 months of life and 9 percent of hunter-harvested juvenile females age 93 to 131 days were determined to be capable of reproduction (Mirarchi et al., 1980).

The male initiates nest site selection by inspecting a site and through nest-soliciting calls and behaviors attempts to attract a female. He then waits for the females' approval or disapproval of the nest site. Nesting can occur in coniferous or deciduous trees, shrubs, vines, human-made structures, and the ground. Nests are flimsy and have little insulation value (Mirarchi and Baskett, 1994). Pair bonds persist through at least one season and possibly through winter (Mackey, 1965). The first brood generally appears from late February to early March and one to two months later at northern latitudes. The squabs hatch 14 days after eggs are laid and fledge 15 days after hatching (Hitchcock and Mirarchi, 1984). Later broods depend on the fate of the first clutch. Thirty days are required between a successful clutch and a subsequent clutch (Hanson and Kessock, 1963). Clutches generally consist of two eggs. The average number of young fledged annually per breeding pair is 3.6 (Mirarchi and Baskett, 1994).

Both parents participate in the incubation process as well as feeding. A unique secretion of the crop wall, called "crop milk", is produced by both the male and female and is used for feeding young (Lewis, 1993).

Behavior and Social Organization

As a migratory species, mourning doves spend most of the winter within the southern portion of their breeding range from the southern United States to western Panama in Central America (Aldrich, 1993). The mourning dove flies singly or in flocks of 2 or more. Paired mourning doves are typically territorial during nesting and defend the area surrounding the nest and cooing perche, with males being aggressive toward other birds, particularly predators. Unmated males defend individual cooing perches. Attack-charge and attack-flight displays are performed and directed toward intruders (Mirarchi and Baskett, 1994).

3.3.18 Greater Roadrunner (*Geococcyx californianus*)[3]

The Greater Roadrunner is in the order Cuculiformes, family Cuculidae. This large, slender bird thrives in arid regions but is as equally adaptable to the Colorado Foothills and the loblolly pines in western Louisiana. It is renowned for its opportunistic feeding habits and has been known to eat its own young during food shortages (Hughes, 1996).

Distribution

The greater roadrunner lives in a broad area of the southern United States and portions of Northern Mexico. In California, they range from the Sacramento Valley to Owens Valley and continue into southern California where they are widespread. They also live in southern Nevada, southwest Utah, and parts of Arizona, New Mexico, Colorado, Kansas, Missouri, Arkansas, Louisiana, and Texas. In Mexico, they can be found from the Pacific slope of Mexico to northern Sinaloa, the interior south to northern Michoacan and Hidalgo, and the Atlantic slope to Tiamaulipas (Hughes, 1996).

Body Size and Weight

The greater roadrunner is a large, slender, terrestrial cuckoo. Mean mass is 320 g for males and 290 g for females. Western birds are generally larger than eastern birds while males are larger than females (Hughes, 1996).

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3 New species accounts compiled for ARAMS.

TABLE 3-83
Body Weights (g) for the Greater Roadrunner (*Geococcyx californianus*)

Location	Sex	N	Mean	Reference
a	Unknown (adults)	23	317.3	Dunning, 1993
a	Unknown (adults)			
a	Males (adults)	23	376	
a	*Females (adults)*			
a	Unknown (juveniles)	8	319.12	
a	Unknown (adults early winter)	4	286.3	
Oklahoma	Unknown(adults midwinter)	4	279.8	Geluso, 1969
		4	478	Geluso, 1970
		3	314.7	

[a] Not stated

Food Habits and Diet Composition

The greater roadrunner is omnivorous eating insects, spiders, scorpions, centipedes, millipedes, lizards, small snakes, birds, eggs, rodents carrion, and plant material (Hughes, 1996). They are opportunistic feeders and animal food makes up 90 percent of their diet. Fruit and seeds are eaten seasonally (Bryant, 1916).

TABLE 3-84
Diet Composition of the Greater Roadrunner (*Geococcyx californianus*)

Location	Prey Taxon	Percent Volume	Reference
California (percent volume based on total volume of food in gizzard)	Scorpiones	3.7	Bryant, 1916
	Araneae	0.7	
	Isopoda	<1	
	Orthoptera	36.8	
	Hemiptera	5	
	Coleoptera	18.2	
	Hymenoptera	4.2	
	Diptera	<1	
	Lepidoptera	7.6	
	Iguanidae	3.7	

TABLE 3-84
Diet Composition of the Greater Roadrunner (*Geococcyx californianus*)

Location	Prey Taxon	Percent Volume	Reference
	Columbridae	<1	
	Passeriformes	1.7	
	Rodentia	2.3	
	Lagomorpha	1.1	
	Anacardiacea	8.4	
	Cactaceae	0.4	
	Other plant material	1.1	
Arizona	Orthoptera	62	Gorusch, 1932
	Other insects	23.6	
	Other reptiles	6	
	Passeriformes	6.4	
	Vegetation	2	
Not stated	Arthropods	76.5	Calder and Schmidt-Nielsen, 1967
	Small vertebrates	8.8	
	Plant material	9.9	
Texas (percent volume based on total number of food items in gizzard)	Isopoda	1.4	Parmley, 1982
	Orthoptera	30.4	
	Coleoptera	11.6	
	Other insects	33.3	
	Bufonidae	4.3	
	Unidentified amphibians	1.4	
	Iguanidae	2.9	
	Teiidae	5.8	
	Columbridae	4.3	
	Other reptiles	2.9	
	Rodentia	1.4	

Food Consumption Rate

In one day, a hand reared adult was found to consume 336 grasshoppers, 17 scorpions, 28 sowbugs, 7 caterpillars, 3 chrysalids, 14 angleworms, 39 moths, 1 butterfly, 14 centipedes, 16 spiders, 2 tarantulas, 3 walking sticks, 3 small toads, 3 horned lizards, 6 green lizards, 8 small lizards, and 1 mouse during a foraging expedition (Sutton, 1915).

Using Eq. 9 and assuming a mean body weight of 0.293 kg (as calculated from above table using adults) a food consumption rate of 0.089 kg/kg BW/day was estimated. A fresh weight of 0.23 kg/kg BW/day can be calculated using Eq. 18 and assuming a diet of 85.6 percent insects, 6 percent reptiles, and 6.4 percent birds (Gorusch, 1932) with respective water contents of 61, 66, and 68 percent as presented in Table 3-4. (Note: If other body weight values are used, then the rate should be recalculated.)

Water Consumption Rate

Roadrunners can generally maintain weight without drinking water if they are eating prey with high water content such as rodents and reptiles (Dunson et al., 1976). If water is available however, the roadrunner will drink copiously (Woods, 1960). Using Eq. 20 and a mean body weight of 0.293 kg a water consumption rate of 0.88 L/kg BW/day can be calculated. (Note: If other body weight values are used, then the rate should be recalculated.)

Soil Ingestion

No information was found on soil ingestion in the literature. Beyer et al. (1994) reported soil ingestion of 9.3 percent of diet for wild turkeys. Because greater roadrunners also forage on the ground, it is assumed that roadrunners would have a comparable soil ingestion to that of wild turkeys. However, it should be noted that 9.3 percent is likely an upperbound value and therefore, its use would be very conservative.

Respiration Rate

Oxygen consumption in adults is 0.92 $\pm$ 0.09 mL/g /hr at air temperatures of 27-36 °C. Above 36 °C, oxygen consumption rate increases. Respiratory rates were recorded as at 29.1 breaths/min (Calder and Schmidt-Nielsen, 1967). Using Eq. 22 and assuming a body weight of 0.293 kg an inhalation rate of 0.54 m^3/day can be estimated. (Note: If other body weight values are used, then the rate should be recalculated.)

Metabolism

The greater roadrunner has developed several behavioral and physiological adaptations to arid regions. Water is conserved through reabsorption through mucosa (Ohmart et al, 1970). Generalized reduction in activity in the afternoon results in less heat dissipation and water expenditures for evaporative heat loss (Calder, 1967b).

Habitat Requirements

The roadrunner is typically found in semiarid to arid open country with scattered scrub. Shrub cover ranges from low to 50 percent while brush layers of 2-3 m high are most common (Folse, 1974). Greater roadrunners can live in altitudes ranging from –60 to 2300 m (200 to 7500 ft; Small, 1994). In some areas, roadrunners can be found in lowland and mesa riparian woodlands (Hamilton, 1962) as well as canyons. They are occasionally found in open farmlands and sparsely populated suburban developments. The greater roadrunner avoids urban areas, heavier deciduous and coniferous woodland (Lehman, 1994), continuous prairie, and bare desert (Hughes, 1996).

Home Range

Home range is noted as being the same as territory (see Behavior and Social Organization).

Population Density

Estimates of population density in south Texas are 3.1 and 2.5 individuals/km^2 (Folse, 1978). Estimates in California were as high as 4 individuals/km^2 (Bryant, 1916). Populations are most abundant in areas that receive at least 140 days of sunshine annually and have very low humidity. Root calculated an observed maximum density of 0.32 individuals per party hour. This rate was estimated by dividing the total number of individuals seen at a given site by the total number of hours spent counting by the groups of people in separate parties at a given site (Root, 1988).

Population Dynamics/Survival

Not much data exists on survivorship but one individual was noted to be at least 7 years old. Captive birds have lived up to 9 years (Smith, 1979). Minimum overwinter survival estimates for adults in Texas is 60 percent (Folse, 1978).

Reproduction/Breeding

The greater roadrunner is monogamous and maintains long-term pair bonds. Pair formation begins in February or March and can start even later in more northerly populations. Once pair bonds are formed a copulatory period occurs at the prospective nest site (Whitson, 1975). Nests are generally located in isolated thickets of small trees, bushes, and cactus and close to short grass areas (Folse, 1978) making foraging and courtship displays possible (Hughes, 1996). Nest construction is generally completed by the female, while the male collects nest material (Whitson, 1975).

The first brood per season usually occurs from late March through May but peak nesting varies by location. In general only one brood is reared per season. However, second broods may appear as early as May, while nesting season may continue until September. If nest predation occurs, clutch replacement is common. Mean clutch size is 4 eggs in Texas (Folse, 1978) and 4.6 eggs in Arizona with a range of two to seven eggs (Ohmart, 1973), though clutch size is highly variable. Both sexes incubate the eggs and feed and protect the young (Hughes, 1996). It also appears that roadrunners maintain nests with young at varying stages of development. Bryant (1916) described a report of a roadrunner nest with one fresh egg, one egg ready to hatch, two featherless chicks, and two fledglings.

Behavior and Social Organization

During breeding, mated pairs maintain a territory that is defended by both sexes though the male takes on more responsibility in defense (Hughes, 1996). Established pairs remain on their territory year round. Average territory size in southern California is 0.7-0.8 km per mated pair (Bryant, 1916). In Arizona, average territory size was reported as 0.8 km (Hughes, 1996).

The greater roadrunner is a solitary bird being found singly or in breeding pairs. Flying is limited for the roadrunner though they can glide from the nest or high perch (Hughes, 1996). The greater roadrunner can run at speeds above 30 km/hour for long distances (Kavanau and Ramos, 1970).

3.3.19 Burrowing Owl (*Speotyto cunicularia*)[2]

The burrowing owl is in the order Strigiformes, family Strigidae. This owl is unique among North American owls in that it is diurnal, forms loose colonies, and is very tolerant of human activity (Haug et al. 1993).

Distribution

The burrowing owl has a very broad distribution in the Americas. This species occurs in suitable habitat throughout western North America, from southern Canada to southern Mexico (Johnsgard, 1988b, Haug et al., 1993). Populations also occur in southern Florida, the western Caribbean islands, and in Central and South America to Tierra del Fuego.

Body Size and Weight

The burrowing owl is a small owl with total body lengths of males and females ranging from 19 to 25 cm (Haug et al., 1993). Earhart and Johnson (1970) report that, in contrast to other North American owls, male borrowing owls are longer winged and heavier than females. More recent data do not support this observation (Haug et al., 1993). Body weights of borrowing owls from several locations are presented in Table 3-85.

TABLE 3-85
Body Weights (g) for Burrowing Owls (*Speotyto cunicularia)*

Location	Sex	N	Mean	Reference
Colorado	Male	38	146.3±1.9 [a]	Haug et al., 1993
	Female	31	156.1±3.6	
Florida	Male	111	148.8±1.5	Haug et al., 1993
	Female	162	149.7±1.7	
Throughout North America	Male	31	158.6 (120-228)[b]	Earhart and Johnson, 1970
	Female	15	150.6 (129-185)	

[a] mean○ SE
b mean (range)

Food Habits and Diet Composition

Burrowing owls are opportunistic feeders, foraging on arthropods, small mammals, and small birds (Earhart and Johnson, 1970; Johnsgard, 1988b; Haug et al., 1993; Table 28). Diets vary by season, according to availability of prey (Thomsen, 1971; Marti, 1974; Haug et al., 1993). Food habits of burrowing owls from several locations are summarized in Table 28. Size of prey taken by burrowing owls is small; mean weight is 3 g with 91.2 percent being ≤1 g (Marti, 1974). Vegetation observed in diet of owls from California is attributed to stomach contents of prey (Thomsen, 1971; Table 3-86).

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2 Text directly from Sample et al. (1997a).

TABLE 3-86
Diet Composition of Burrowing Owls *(Speotyto cunicularia)*

Location	Prey Taxon	Percent	Comments	Reference
California	Meadow vole	27.63	Values represent mean total biomass observed in pellets over four seasons	Thomsen, 1971
	Jackrabbit	2.28		
	Pocket gopher	1.25		
	Norway rat	0.38		
	House mouse	0.25		
	Hoary bat	0.025		
	Western meadowlark	0.075		
	Blackbird	0.1		
	Shorebirds	0.05		
	Unidentified birds	3.05		
	Toad	0.28		
	Jerusalem cricket	11.25		
	Unidentified orthoptera	0.075		
	Coleoptera	16.05		
	Isopoda	0.05		
	Sand and dirt	4.13		
	Stones	0.9		
	Vegetation	32.35		
Idaho	Mammals	68	Values represent percent biomass in pellets	Gleason and Craig, 1979
	Birds	1		
	Amphibians	3		
	Arachnids	4		
	Insects	25		
Colorado	Mammals		Values represent mean percent of numbers observed in pellets collected over six months	Marti, 1974
	Sylvilagus spp.	0.23		
	Perognathus spp.	0.17		
	Reithrodontymys spp.	1.17		
	Peromyscus maniculatus	5.38		
	Microtus ochrogaster	2.03		
	Other mammals	0.22		
	Birds	0.12		
		0.03		

TABLE 3-86
Diet Composition of Burrowing Owls *(Speotyto cunicularia)*

Location	Prey Taxon	Percent	Comments	Reference
	Reptiles	0.38		
	Crayfish			
	Insects	9.78		
	Gryllidae	9.37		
	Acrididae	0.30		
	Cicindelidae	50.27		
	Carabidae	10.13		
	Scarabidae	2.83		
	Silphidae	3.15		
	Tenebrionidae	1.40		
	Curculionidae	2.58		
	Other insects	0.23		
	Spiders			

[a] Mean and range of observations from three locations

Food Consumption Rate

Coulombe (1970) reports the mean (±STD) daily energy expenditure by burrowing owls in summer (21-26°C) and winter (10°C) to be 0.18 ○ 0.05 kcal/g/d and 0.14±0.036 kcal/g/d, respectively. Using Eq. 18 [assuming a diet of 90.7 percent invertebrates and 9.3 percent small mammals (Table 3-86; Marti, 1974), caloric densities and water content of invertebrates and small mammals of 5.278 kcal/g and 76.3 percent (Bell, 1990) and 5.163 kcal/g (Golley, 1961) and 68 percent (Table 3-4), respectively], mean daily food consumption by burrowing owls is estimated to be 0.046 g/g/d in summer and 0.036 g/g/d in winter. These estimates are substantially lower than that estimated using the same assumptions and Eq. 9 (summer = 0.165 g/g/d; winter = 0.153 g/g/d).

Water Consumption Rate

No literature data were located concerning water ingestion rates for burrowing owls. Using Eq. 20, owls weighing 0.15-0.16 kg are estimated to consume approximately 0.11 L/kg/d.

Soil Ingestion

Sand, dirt, and rocks accounted for 0.12 to 15 percent of the volume of pellets of burrowing owls from California (mean ±STD: 5.0±5.9;Thomsen, 1971).

Respiration Rate

Burrowing owls are adapted to high CO_2 and low O_2 concentrations they experience in burrows. While respiration rates for bobwhite increased sharply in response to decreasing

O_2 concentration, that for burrowing owls remained constant (Boggs and Kilgore, 1983). Average (±SE) respiration rates for resting burrowing owls under normal conditions is 129±4.5 mL/min. or 1.12 m^3/kg/d (Boggs and Kilgore, 1983). This measured value is almost twice that estimated using Eq. 22: 0.6 m^3/kg/d for owls weighing 0.15-0.16 kg.

Metabolism

The metabolism and physiology of burrowing owls was extensively studied by Coulombe (1970). Oxygen consumption varied in relation to ambient temperature and was described by the following

$$VO_2 = 1.44 - 0.0324\,(T_A - 13.66) \text{ for } T_A < 25°C,$$

$$VO_2 = 1.05 \pm 0.56\ (\bar{x} \pm 95 \text{ percent CI}) \text{ for } T_A\ 25\text{-}37°C,$$

and

$$VO_2 = 1.32e^{0.0911\,(T_A - 41.27)} \text{ for } T_A > 37°C,$$

where

VO_2 = oxygen consumption in cm^3/g/h,

T_A = ambient temperature.

Habitat Requirements

The typical habitat of burrowing owls consists of dry, open, treeless plains, heavily grazed or low-quality grassland, or desert vegetation (Johnsgard, 1988; Haug et al., 1993). Other areas include golf courses, cemeteries, road-sides, airports, vacant lots, etc. (Haug et al., 1993). Borrowing owls are frequently associated with burrowing mammals (MacCracken et al., 1985; Rich, 1986; Green and Anthony, 1989; Desmond and Savidge, 1996). Although the presence of burrows appears to be a critical requirement for western owls, owls in Florida usually excavate their own burrows (Haug et al., 1993). In Saskatchewan, burrowing owls foraged in grass-forb areas but avoided croplands and grazed pasture (Haug and Oliphant, 1990).

Home Range

Although the mean home range size of owls in Saskatchewan was 241 ha (range = 14-481 ha; Haug and Oliphant, 1990), 95 percent of all movement occurred within 600 m of nest burrows. Territories are generally limited to the immediate area around burrows; adjacent pairs may share foraging ranges (Johnsgard, 1988). In California, Thomsen (1971) observed a mean territory size of 0.8 ha (range: 0.04-1.6 ha).

Population Density

Nest density is probably influenced by the availability of nest burrows (Johnsgard, 1988). In the Imperial Valley of California, mean (±STD) density was 0.035±0.018 individuals/ha (range: 0.003-0.06; Coulombe, 1971). Desmond and Savidge (1996) report that burrowing owl densities varied according to the size of the prairie dog towns they were associated with; small towns (<35 ha) had 0.1-30 owls/ha while large towns (>35 ha) had 0.03-0.4 owls/ha. Densities of owls, within owl clusters in large prairie dog towns ranged from

0.9-2.5 owls/ha. As the size of the prairie dog town increased, the abundance of owls increased, but their density decreased (Desmond and Savidge, 1996).

Population Dynamics/Survival

Evidence suggests that burrowing owl populations are declining across much of their range (Haug et al., 1993). The annual survival of burrowing owls in California was 30 percent for juveniles and 80 percent for adults (Thomsen, 1971). Longevity in excess of 8 years has been reported (Haug et al., 1993).

Reproduction/Breeding

Data on reproduction in burrowing owls was derived from Martin (1973), Johnsgard (1988), Green and Anthony (1989), and Haug et al. (1993). Burrowing owls nest in underground burrows that they may or may not excavate themselves. Eggs may be present from mid-March to May. Clutch sizes range from 3 to 12 eggs but are typically 6 to 8 eggs. Incubation lasts 27 to 30 days. Hatching success ranges from 55 to 90.3 percent. The nestling period lasts 40 to 45 days. Generally, only one clutch/year is produced. Burrowing owls are sexually mature at 1 year of age.

Behavior

Burrowing owls are migratory only in the northern part of their range; birds in Florida and southern California are sedentary (Johnsgard, 1988). While burrowing owls are generally crepuscular in their foraging (Coulombe, 1971), hunting has been observed during both day and night. Insects are generally hunted by day and small mammals at night (Haug et al., 1993). Thomsen (1971) observed dust bathing in this species.

Social Organization

Burrowing owls are semicolonial, forming loose colonies (Haug et al., 1993). Migrant birds, however, are solitary.

3.3.20 Belted Kingfisher (*Ceryle alcyon*)[1]

Belted Kingfisher (*Ceryle alcyon*, formerly *Megaceryle alcyon*) belongs to the order Coraciiformes, family Alcedinidae. Kingfishers are stocky, short-legged birds with large heads and bills. They exist on a diet mostly of fish, which they catch by diving, from a perch or the air, head first into the water. They nest in burrows in earthen banks that they dig using their bills and feet. The belted kingfisher is a medium-sized bird (33 cm bill tip to tail tip) that eats primarily fish. It is one of the few species of fish-eating birds found throughout inland areas as well as coastal areas.

Distribution

The belted kingfisher's range includes most of the North American continent; it breeds from northern Alaska and central Labrador southward to the southern border of the United States (Bent, 1940). Two subspecies sometimes are recognized: the eastern belted kingfisher (*Ceryle alcyon alcyon*), which occupies the range east of the Rocky Mountains and north to

[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

Quebec, and the western belted kingfisher (*Cercyle alcyon caurina*), which occupies the remaining range to the west (Bent, 1940).

Body Size and Weight

The sexes are similar in size and appearance, although the female tends to be slightly larger (Salyer and Lagler, 1946). Bent (1940) reported that western populations are somewhat larger than eastern ones. Nestlings reach adult body weight by about 16 days after hatching, but then may lose some weight before fledging (Hamas, 1981). Body weights of Belted Kingfishers from different locations throughout their range are presented in Table3-87.

TABLE 3-87
Body Weights (g) for the Belted Kingfisher (*Ceryle alcyon)*

Location	Sex	Mean	Reference
Pennsylvania	Both	148 ± 20.8	Powdermill Nature Center (unpublished)
Pennsylvania	Both	136 ± 15.6	Brooks & Davis, 1987
Ohio	Both	158 ± 11.5	Brooks & Davis, 1987
Minnesota	At Hatching	10-12	Hamas, 1981
Pennsylvania	At Fledging	148 ± 13.3	Brooks & Davis, 1987
Ohio	At Fledging	169 ± 11.9	Brooks & Davis, 1987

Food Habits and Diet Composition

Belted kingfishers generally feed on fish that swim near the surface or in shallow water (Salyer and Lagler, 1946; White, 1953; Cornwell, 1963). Davis (pers. comm. in Prose, 1985) believes that these kingfishers generally catch fish only in the upper 12 to 15 cm of the water column. Belted kingfishers capture fish by diving either from a perch overhanging the water or after hovering above the water (Bent, 1940). Fish are swallowed whole, head first, after being beaten on a perch (Bent, 1940). The average length of fish caught in a Michigan study was less than 7.6 cm but ranged from 2.5 to 17.8 cm (Salyer and Lagler, 1946); Davis (1982) found fish caught in Ohio streams to range from 4 to 14 cm in length. Several studies indicate that belted kingfishers usually catch the prey that are most available (White, 1937, 1953; Salyer and Lagler, 1946; Davis, 1982). Diet therefore varies considerably among different water bodies and with season. Although kingfishers feed predominantly on fish, they also sometimes consume large numbers of crayfish (Davis, 1982; Sayler and Lagler, 1946), and in shortages of their preferred foods, have been known to consume crabs, mussels, lizards, frogs, toads, small snakes, turtles, insects, salamanders, newts, young birds, mice, and berries (Bent, 1940). Parents bring surprisingly large fish to their young. White (1953) found that nestlings only 7 to 10 days old were provided fish up to 10 cm long, and nestlings only 2 weeks old were provided with fish up to 13 cm in length. After fledging, young belted kingfishers fed on flying insects for their first 4 days after leaving the nest, crayfish for the next week, and by the 18th day post-fledging, could catch fish (Salyer and Lagler, 1946). Food preferences of belted kingfishers are summarized in Table 3-88.

TABLE 3-88
Diet Composition of Belted Kingfishers (*Ceryle alcyon)*

Location	Prey Taxon	Percent Volume	Reference
Michigan-Lake	Trout	17[a]	Alexander, 1977
	Non-Trout Fish	29	
	Crustacea	5	
	Insects	19	
	Amphibians	27	
	Birds and Mammals	1	
	Unidentified	2	
Michigan-Trout Streams	Trout	30[a]	Salyer & Lagler, 1946
	Other Game & Pan Fish (e.g., perch, centrarchids)	13	
	Forage Fish (e.g., minnow, stickleback, sculpins)	15	
	Unidentified Fish	1	
	Crayfish	41	
	Insects	<1	
Nova Scotia/Riparian-Streams	Salmon Fry	11[b]	White, 1936
	Salmon (1-yr-old)	42	
	Salmon (2-yr-old)	1	
	Trout	15	
	Sticklebacks	30	
	Killifish	<1	
	Suckers	<1	
Ohio-Creek	Crayfish	13[c]	Davis, 1982
	Cyprinids	76	
	Minnows	13	
	Stonerollers	38	
	Unidentified	26	
	Other Fish	10	

[a] percent wet weight; stomach contents.
[b] percent of total number of prey; fecal pellets.
[c] percent of total number of prey brought to nestlings.

Food Consumption Rate

Kingfishers in northcentral lower Michigan had an estimated food ingestion rate of 0.5 g/g BW/day (Alexander, 1977). Nestlings in Nova Scotia were found to have a range from 1 to 1.75 g/g BW/day (White, 1936). Using Eq. 9 and a mean body weight of 0.147 kg (as calculated using the above table and adult birds) an ingestion rate of 0.12 kg/kg BW/day. Equation 18 was used to estimate a fresh weight (0.48 kg/kg BW/day) assuming a diet of 100 percent fish (White, 1936). A water content of 75 percent for bony fish was used (Table 3-4). (Note: If other body weight values are used, then the rate should be recalculated.)

Water Consumption Rate

No data concerning water ingestion rates for the belted kingfisher were available in the literature reviewed. A water consumption rate of 0.11 L/kg BW/day can be estimated using the Eq. 20 and body weights from Powdermill nature center (unpublished). (Note: If other body weight values are used, then the rate should be recalculated.)

Soil Ingestion

No information was found in the literature about soil ingestion. However, as a picsivorous species that primarily feeds on fish near the surface of the water (Salyer and Lagler, 1946; White, 1953; Cornwell, 1963), soil ingestion is expected to be negligible.

Respiration Rate

No data concerning inhalation rates of belted kingfisher were available in the literature. An inhalation rate for the belted kingfisher of 0.64 m^3/kg BW/day can be estimated using Eq. 22 and body weights from Powdermill nature center (unpublished). (Note: If other body weight values are used, then the rate should be recalculated.)

Metabolism

No data concerning the metabolism of belted kingfisher were available in the literature. Estimates of both a basal and free living metabolic rate for the belted kingfisher can be calculated using equations from Lasiewski and Dawson (1967) and Nagy (1987) with body weights from Powdermill nature center (unpublished). The mean basal rate was 132 kcal/kg BW/day while the mean free living rate was 327 kcal/kg BW/day. (Note: If other body weight values are used, then the rate should be recalculated.)

Habitat Requirements

Belted kingfishers are typically found along rivers and streams and along lake and pond edges (Hamas, 1974). They are also common on seacoasts and estuaries (Bent, 1940). They prefer waters that are free of thick vegetation that obscures the view of the water and water that is not completely overshadowed by trees (Bent, 1940; White, 1953). Kingfishers also require relatively clear water in order to see their prey and are noticeably absent in areas when waters become turbid (Bent, 1940; Davis, 1982; Salyer and Lagler, 1946). White (1953) suggested that water less than 60 cm deep is preferred. They prefer stream riffles for foraging sites even when pools are more plentiful because of the concentration of fish at riffle edges (Davis, 1982). Belted kingfishers nest in burrows within steep earthen banks devoid of vegetation beside rivers, streams, ponds, and lakes; they also have been found to nest in slopes created by human excavations such as roadcuts and landfills (Hamas, 1974). Sandy soil banks, which are easy to excavate and provide good drainage, are preferred (Brooks and Davis, 1987; Cornwell, 1963; White, 1953). In general, kingfishers nest near suitable fishing areas when possible but will nest away from water and feed in bodies of water other than the one closest to home (Cornwell, 1963).

Home Range

During the breeding season, belted kingfishers require suitable nesting sites with adequate nearby fishing. During spring and early summer, both male and female belted kingfishers defend a territory that includes both their nest site and their foraging area (Davis, 1982). By autumn, each bird (including the young of the year) defends an individual feeding territory only (Davis, 1982). The breeding territories (length of waterline protected) can be more than twice as long as the fall and winter feeding territories, and stream territories tend to be longer than those on lakes (Davis, 1982; Salyer and Lagler, 1946). Foraging territory size is inversely related to prey abundance (Davis, 1982). Mean territory sizes found in Ohio include 1.03 km of shoreline for breeding individuals in early summer and non-breeding individuals in late summer and 0.39 km of shoreline for non-breeding individuals in late summer (Brooks and Davis, 1987; Davis, 1980). Brooks and Davis (1987) also reported territory sizes of 2.19 km of shoreline in Pennsylvania.

Population Density

Breeding densities of between 0.11 and 0.6 pair per 10 km of river shoreline have been recorded, with density increasing with food availability (Brooks and Davis, 1987; White, 1936).

Population Dynamics/Survival

Kingfishers are sensitive to disturbance and usually do not nest in areas near human activity (White, 1953; Cornwell, 1963). Kingfishers typically breed in the first season after they are born (Bent, 1940). Fledging success depends on food availability, storms, floods, predation, and the integrity of the nest burrow but can be as high as 97 percent (M. J. Hamas, pers. comm.). Dispersal of young occurs within a month of fledging (White, 1953). No data concerning annual survivorship rates were found.

Reproduction/Breeding

Belted kingfishers are not colonial nesters and will defend an unused bank if it lies within their territory (Davis, 1982). In migrating populations, the males arrive before the females to find suitable nesting territories (Davis, 1982). Kingfishers excavate their burrows in earthen banks, forming a tunnel that averages 1 to 2 m in length, although some burrows may be as long as 3 to 4 m (Hamas, 1981; Prose, 1985). The burrow entrance is usually 30 to 90 cm from the top of the bank (Bent, 1940; White, 1953) and at least 1.5 m from the base (Cornwell, 1963). Burrows closer to the top may collapse, and burrows too low may flood (Brooks and Davis, 1987). Burrows may be used for more than one season (Bent, 1940). Five to seven eggs are laid on bare substrate or on fish bones within the burrow (Hamas, 1981; White, 1953). One clutch is laid per year (Brooks and Davis, 1987; Hamas, 1975) and mean clutch sizes of 5.8 ± 0.7 SE and 6.8 ± 0.4 SE have been recorded for kingfishers in Pennsylvania and Ohio, respectively (Brooks and Davis, 1987). Only one adult, usually the female, spends the night in the nest cavity; males usually roost in nearby forested areas or heavy cover (Cornwell, 1963). Both parents incubate eggs and feed the young (Bent, 1940). Incubation lasts 22 days (Hamas, 1975), and chicks fledge at 23 days post-hatch (Bent, 1940). After fledging, the young remain with their parents for 10 to 15 days (Sayler and Lagler, 1946).

Behavior and Social Organization

This kingfisher breeds over most of the area of North America and winters in most regions of the continental United States (National Geographic Society, 1987). Although most northern kingfishers migrate to southern regions during the coldest months, some may stay in areas that remain ice-free where fishing is possible (Bent, 1940). Fall departures end in mid-October in Maine, in mid-November in New York, South Dakota, Wisconsin, and Nebraska, and in mid-December in Massachusetts, and New Jersey (Bent, 1940). Spring arrivals begin in mid October in Pennsylvania, Rhode Island, and Missouri, mid-March in New York, Connecticut, Illinois, and Wisconsin, and in early April in Maine and Nova Scotia (Bent, 1940).

During the breeding season, pairs establish territories for nesting and fishing (Davis, 1982); otherwise, belted kingfishers are solitary.

3.3.21 Northern Flicker (*Colaptes auratus*)[3]

The northern flicker is in the order Piciformes, family Picidae. It is the only species of flicker (*Colaptes*) found in North America. There are five subspecies, distinguished by size, plumage, and distribution. *C.a. auratus* occurs in eastern North America and *C.a. cafer* is found in western North America, where the ranges of these two subspecies overlap there is some hybridization. *C.a. chrysoides* is found in the Sonoran desert, and there is minimal hybridization with other overlapping subspecies. *C.a. mexicanoides* occurs in Mexico and Central America and *C.a. chrysocaulosus* is found in Cuba and the Grand Cayman (Moore, 1995).

Distribution

The northern flicker is a common and widespread species throughout North America, occurring from Alaska to central Mexico. The northern populations migrate to more southern portions of the range during the fall, but return in the spring to breed, other populations are resident throughout the year (Moore, 1995).

Body Size and Weight

There is little variation between the sexes; however, size is variable among the different sub-species. The average size of an adult is 28-31 cm. Body weights for adults average 148.1 ± 12.5 SD g (Tobalske, 1996).

Food Habits and Diet Composition

Northern flickers primarily forage on the ground for insects, seeds, and fruits, but have occasionally been observed foraging in trees (Brackbill, 1957). Flickers have powerful bills and feed by probing and hammering in the soil (Moore, 1995).

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[3] New species accounts compiled for ARAMS.

TABLE 3-89
Food Habits of the Northern Flicker (*Colaptes auratus)*

Location	Food Items	Percent Occurrence	Reference
Eastern N. Amer.	Animal	60.9	Beal, 1911
	Ants	49.8	
	Coleoptera	5.1	
	Hemiptera	0.9	
	Orthoptera	2.4	
	Lepidoptera	1.3	
	Miscellaneous	1.4	
	Plant	39.1	
Western N. Amer.	Animal	67.7	Beal, 1911
	Ants	53.8	
	Coleoptera	6.6	
	Hemiptera	1.8	
	Orthoptera	1.5	
	Lepidoptera	2.1	
	Miscellaneous	1.9	
	Plant	32.3	

Food Consumption Rate

No data were available in the literature regarding food consumption by northern flickers. Using Eq. 9, and assuming a mean body weight of 0.148 kg (Tobalske, 1996), a food consumption rate of 0.11 kg/kg BW/day can be calculated. A fresh weight of 0.42 kg/kg BW/day can be estimated assuming a diet of 67 percent invertebrates and 32 percent plants (Beal, 1911) with respective water contents of 61 and 85 percent (Table 3-4). (Note: If using other body weight values, then the rate should be recalculated.)

Water Consumption Rate

Flickers are rarely observed drinking water (Moore, 1995). Using Eq. 20 and a body weight of 0.148 kg, a water consumption rate of 0.11 L/kg BW/day can be estimated. (Note: If using other body weight values, then the rate should be recalculated.)

Soil Ingestion Rate

No data regarding soil ingestion rates of northern flickers were available in the literature. Beyer et al. (1994) reported soil ingestion of 9.3 percent of the diet for wild turkeys. Because northern flickers also forage on the ground, it is assumed that their soil ingestion rate would be comparable to that of wild turkeys. However, it should be noted that 9.3 percent is likely an upperbound value and therefore, its use would be very conservative.

Respiration Rate

No literature data were found regarding the respiration rate of flickers. Using Eq. 22 and a mean body weight of 0.148 kg, an inhalation rate of 0.64 m^3/kg BW/day was estimated. (Note: If using other body weight values, then the rate should be recalculated.)

Metabolism

No information was found in the literature on metabolism of northern flickers.

Habitat Requirements

Northern flickers occur in a variety of woodland, savanna, and forest edge habitats. Tree species composition, as well as nest tree selection, is highly variable and it appears that an open vegetation structure is more important than specific species of tree (Conner et al., 1975; Hubbard, 1965). Populations are often abundant in burned over forests or in clear-cuts if scattered snags and shrubs remain (Conner et al., 1975; Conner and Atkinson, 1977). Northern Flickers are also well adapted to human habitats and will commonly breed in urban, suburban, and rural areas. Nest cavities are usually excavated in dead and diseased tree trunks or large branches. They roost at night in tree branches or in cavities, but will also roost on buildings and under bridges (Moore, 1995).

Home Range

Royall and Bray (1980) reported that the home range of northern flickers in Jefferson County, Colorado was between 48 and 101 ha.

Population Density

In Ponderosa pine forests in Arizona, the population density of northern flickers was 10 individuals in a 40 ha area or 0.25 bird/ha (Scott and Oldemeyer, 1983). In California, an average of four breeding pairs per 40 ha (0.1 pair/ha) were reported in a burned pine-fir forest, but only 0.36 pairs per 40 ha (0.01 pair/ha) were found in unburned areas (Raphael and White, 1984).

Population Dynamics / Survival

Populations in the U.S. and Canada have been declining presumably as a result of limited availability of suitable nest sites, in part due to removal of snags during timber harvest operations, and competition from the introduced European starlings. Estimated survival to hatching stage was 78 percent and survival to advanced hatching stage (17days) was 86 percent (Moore, 1995). The overall nest survival rate is estimated to be 73 percent (Dennis, 1969). No data was found on adult survival rates. The maximum reported longevity is nine years two months for the eastern subspecies and seven years seven months for the western subspecies (USGS Bird Banding Laboratory, May 2000).

Reproduction and Breeding

Northern flickers are monogamous and activities such as nest construction, territorial defense, and parental care are shared by both parents throughout the breeding season. Both males and females can breed at one year of age. The breeding season begins in April and extends through early July, with a peak in May. One clutch is laid per season and the number of eggs is variable depending on local populations, latitude, and season (Moore, 1995). Moore and Koening (1986) examined clutch size for 411 birds across a latitudinal gradient and found that the range was between 3 and 12 eggs, with a mean of 6.5 eggs ± 1.4 SD. They also found that birds breeding in early May had a slightly higher clutch size than birds breeding in late May, 7.82 and 6.0 eggs respectively. Incubation lasts approximately 11 days and hatchlings fledge between 24 and 27 days post-hatch (Moore, 1995).

Behavior

Flickers are active during the day, departing from a night roost shortly after sunrise to forage. Flickers spend an estimated 23 percent of the day on the ground foraging for food, but are otherwise perched in trees. They roost for the night at sunset (Moore, 1995). There are no detailed studies on the nature or extent of territory, but breeding pairs will actively defend their nesting site until brooding begins, after which time other birds may establish nests in the same tree (Moore, 1995). Agnostic behavior is most prevalent during the establishment of territories, pair formation, and nest site selection (Short, 1982). The aggressive behavior is highly ritualized, however, and seldom results in physical contact (Moore, 1995).

Social Organization

During the non-breeding season loosely structured groups of flickers may forage together, but they are not considered to be social birds. During the breeding season pair bonds are quite strong and both sexes will defend their mate and breeding territory, as well as share in the parenting responsibilities. One parent will forage for food, while the other stays at or near the nest (Moore, 1995).

3.3.22 Swallows[2]

Swallows are in the order Passeriformes, family Hirundinidae. Eight species of swallows occur in North America: tree swallow (*Tachycineta bicolor*), violet-green swallow (*Tachycineta thalassina*), purple martin (*Progne subis*), bank swallow (*Riparia riparia*), northern rough-winged swallow (*Stelgidopteryx serripennis*), cliff swallow (*Hirundo pyrrhonota*), cave swallow (*Hirundo fulva*), and barn swallow (*Hirundo rustica*) (National Geographic Society, 1987). All are aerial foraging species that forage over open fields or bodies of water (Imhof, 1976).

Distribution

Swallow species are found throughout North America. Tree, bank, northern rough-winged, cliff, and barn swallows breed across the northern 3/4 of the United States into Canada and Alaska (except the rough-winged, which extends only to southern Canada; National Geographic Society, 1987). Violet-green swallows occur in the west, from Alaska to Mexico.

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[2] Text directly from Sample et al. (1997a).

Purple martins breed east of the Rocky Mountains and along the Pacific Coast. Cave swallows occur only in Texas and southern New Mexico (West, 1995).

Body Size and Weight

Swallows are small, long-winged birds. Body lengths range from approximately 13 cm for bank swallows to 20 cm for purple martins. Body masses for North American swallow species range from <15 to approximately 50 g (Table 3-90).

Food Habits and Diet Composition

The diet of swallows consists primarily of insects; however, some plant matter may be consumed (Beal, 1918). The diet composition of swallow species in North America is summarized in Table 3-91. Flies (Diptera) are generally very important food items for swallows, comprising as much as 40 percent of the diet of some species (Quinney and Ankney, 1985; Blancher and McNicol, 1991; Table 34). Chironomid midges are an important food item of tree swallows, accounting for 33 percent of the diet of nestlings (Blancher and McNicol, 1991). Because many swallows forage extensively over water (Brown and Brown, 1995; DeJong, 1996; Robertson et al., 1992; DeGraaf et al., 1981), aquatic prey constitute a significant portion of their diet. Blancher and McNicol (1991) found prey of aquatic origins to account for 64.9, 71, and 54.9 percent of the diet of nestling, egg-laying female, and other adult tree swallows, respectively. Swallows generally consume small insects. Quinney and Ankney (1985) report that 99 percent of the insects consumed by tree swallows are ≤10 mm in length. Blancher and McNicol (1991) observed that ~90 percent of prey were ≤25 mm in length.

Food Consumption Rate

Brown and Brown (1995) report that cliff swallows forage at a rate of 3.4, 3.8, and 3.5 kcal/h during nest building, incubation, and nestling periods, respectively. Female tree swallows in New Brunswick, Canada, were observed to require 5.73±1.40 kJ/g/d (mean±STD; n=10; Williams, 1988). Assuming that the diet consists exclusively of insects (Quinney and Ankney, 1985) and that the energy and water content of insects is 22.09 kJ/g dry weight and 76.3 percent, respectively (Bell, 1990), daily food consumption by tree swallows is 0.198±0.048 g/g/d.

Water Consumption Rate

No literature data were located concerning water ingestion rates for swallows. Estimated water ingestion rates among swallows may range from 0.24 L/kg BW/d to 0.16 L/kg BW/d (based on Eq. 20 and body weights of 15 and 50 g). In practice, water ingestion rates should be recalculated using body weights for species of interest.

Soil Ingestion

Swallows are reported to ingest grit, probably to aid in digestion or as a source of inorganic nutrients (Barrentine, 1980; Mayoh and Zach, 1986). Although Barrentine (1980) found grit in 80 percent of the stomachs of nestling barn swallows, the occurrence of grit in the stomachs of adults was only 22 percent (Gionfriddo and Best, 1996). Among nestlings, particles ranged from 0.84 to 4 mm in diameter, with 4.8±4.5 (mean±STD) particles/stomach (Barrentine, 1980). In contrast, the mean particle size in stomachs of adults was 1.2 mm, with 1◯4 particles/stomach (Gionfriddo and Best, 1996). Grit was found in 35 and 20 percent of the stomachs of nestling and adult tree swallows, respectively (Mayoh and Zach, 1986). The number of particles and the mass of grit was greater in nestings than adults: the number of particles was 10.2◯2.2 (mean◯SE) in nestlings vs 0.8◯0.8 in adults and mass (mg) was 17.2◯2.6 in nestlings vs 6.1◯6.1 in adults. Data relating grit ingestion to food ingestion rate was not found in the literature, however. Consequently estimation of a soil ingestion rate from these data is problematic.

Respiration Rate

No literature data were located concerning inhalation rates for swallows. Eq. 22, although developed for nonpasserine birds, may be used; however, significant uncertainty in the resulting estimate must be acknowledged.

Metabolism

Williams (1988) studied the field metabolism of tree swallows during the breeding season to evaluate whether aerial foraging species have higher energy requirements that other species. Resting and night-time basal metabolic rates were determined to be 79.3◯12.6 and 59.5 mL O_2/h, respectively, for birds weighing 21.6◯1.9 g. The results indicated that swallows have higher metabolic rates than birds with less energy-intensive lifestyles (e.g., ground foraging species). Additional information on the metabolism of swallows is included in a bioenergetics-based model of PCB accumulation by nestling tree swallows (Nichols et al., 1995).

Habitat Requirements

As aerial foraging species, all swallows require open areas that do not inhibit flight activities. Areas that may be used include open fields, farmland, suburban yards, marshes, bodies of water, riparian edge, broken forest, etc. (DeGraaf et al., 1981; Brown and Brown, 1995; Robertson et al., 1992; Bent, 1942; West, 1995; DeJong, 1996). Preferred habitats are generally near water. Some habitats are avoided, for example dense forest, desert, and alpine areas (Brown and Brown, 1995). Prior to human development, nests were placed on cliffs or within tree cavities. Now, many human-made structures such as bridges or buildings may be used for nesting. Proximity to a mud source for nest building may also be a requirement for some species (Brown and Brown, 1995). Purple martins originally nested in tree cavities but now rely extensively on human-made multiroom nest boxes (DeGraaf et al., 1981). As a cavity nester, tree swallows need dead trees (Robertson et al., 1992). Bank and northern rough-winged swallows frequently use burrows in earthen banks near water bodies (DeJong, 1996; Stoner, 1936; DeGraaf et al., 1981).

Home Range

Prior to incubation, tree swallows may travel up to 60 km from nest to forage. However, during incubation and nesting, males may travel 4-5 km and females 2-3 km in search of food (Robertson et al., 1992). Bank and barn swallows generally forage within 0.8 km or less from nest sites (Stoner and Stoner, 1941; DeGraaf et al., 1981). Among cliff swallows, foraging is generally restricted to a 1.5-km radius around the colony; however, birds may travel up to 6 km to forage (Brown and Brown, 1995).

Population Density

Because of their colonial nature and patchy distribution, densities of swallows can be highly variable, difficult to estimate, and dependant on habitat and availability of suitable nest sites. Additionally, density estimates based on breeding pairs are biased because nonbreeding floaters are not accounted for (Robertson et al., 1992). Some representative density estimates follow. Densities of foraging barn swallows of 0.64 individuals/ha have been reported in Illinois (DeGraaf et al., 1981). Breeding densities for barn swallows range from 0.077 pairs/ha in 'favorable' habitat in South Dakota to 0.27 pairs/ha in mixed agricultural/residential habitat in Maryland (DeGraaf et al., 1981). Among tree swallows, breeding densities have been reported to range from 3.5 to 500 pairs/ha, the later estimate resulting from nest boxes placed at an artificially high density (DeGraaf et al., 1981). The breeding density of northern rough-winged swallows in Michigan was approximately 0.18 pairs/ha (Lunk, 1962).

Population Dynamics/Survival

First-year mortality among swallows is high: 68, 79, and 83 percent for cave, tree, and cliff swallows, respectively (West, 1995; Robertson et al., 1992; Brown and Brown, 1995). After the first year, survivorship improves, ranging from 40 to 60 percent (Robertson et al., 1992; Brown and Brown, 1995). For rough-winged swallows, a 33 percent adult survival is required for population maintenance (DeJong, 1996). Maximum longevity in swallows ranges from 5 years (rough-winged swallows; DeJong, 1966) to 11 years (cliff and tree swallows; Robertson et al., 1992; Brown and Brown, 1995).

Reproduction/Breeding

Reproductive parameters for North American swallows are summarized in Table 3-92. Reproductive success for rough-winged swallows in Michigan are reported to be 73, 61, and 65 percent for hatching, fledging, and overall nesting, respectively (Lunk, 1962). Success rates for tree swallows are somewhat higher: hatching success = 88.4 percent, fledging success = 80.2, and overall nesting success = 78.8 percent (Robertson et al., 1995).

Behavior

Most North American swallows are migratory, traveling to winter ranges in the southern United States, Mexico, and South America (DeJong, 1996; West, 1995; Robertson et al., 1992; Brown and Brown, 1995). Many swallows drink water while in flight, tipping their bills into water during low flight (DeJong, 1996; Robertson et al., 1992; Brown and Brown, 1995).

Social Organization

Swallows are generally considered highly social, gregarious birds. Many swallows are colonial, congregating in large breeding colonies. Bank swallow colonies may include 10 to more than 300 nests (DeGraaf et al., 1981). Cliff swallows are the most colonial; colonies of 1000 nests are common, with 3700 nests in the largest colony (Brown and Brown, 1995). Rough-winged swallows are the least social (DeJong, 1996), commonly forming groups of 3 to 12 individuals. These swallows nest singly or in small groups of 2 to 25 pairs, often at edges of bank swallow colonies.

TABLE 3-90
Body Weights (g) for Swallows

Species	Location	Sex and age	N	Mean	Range	Reference
Cave swallow	Yucatan, Mexico	Male: adult	3	19.0		West, 1995
		Female: adult	3	17.7		
	Texas	Both: adult	25	20.4	18.4-22.3	Dunning, 1993
Northern rough-winged swallow	Pennsylvania	Both: adult	47	15.9±0.58	10.3-18.3	Dunning, 1993
	Not stated	Male: adult	9	14.59±0.54		DeJong, 1996
		Female: adult	6	13.3±0.63		
Tree swallow	Southern Ontario	Male: adult > 2 years	86	20.4±1.5	17-24	Robertson et al., 1992
		Female: adult > 2 years	134	21.5±1.7	18-25.5	
	Pennsylvania	Both: adult	82	20.1±1.58	15.6-25.4	Dunning, 1993
Cliff swallow	Nebraska	Male: adult during nesting	6797	23.9		Brown and Brown, 1995
		Female: adult during nesting	3566	24.15		
	California	Both: adult	88	21.6±2.04	17.5-26.7	Dunning, 1993
Purple martin	Maine	Both: adult	22	49.4±1.49		Dunning, 1993
Violet-green swallow	California	Male: adult	16	14.4	13.0-16.3	Dunning, 1993
		Female: adult	15	13.9	12.5-15.2	
Barn swallow	Morocco	Male: adult	1337	16.2	12.1-28.2	Dunning, 1993
		Female: adult	994	15.8	11.0-24.8	
Bank swallow	New York	Both: adult	249	14.6	12.0-18.6	Stoner, 1936

TABLE 3-91
Diet Composition of Swallows in North America

Species	Location	Taxa	Percent volume	Percent frequency	Comments	Reference
Purple martin	Throughout the United States and Canada (n=205)	Hymenoptera	23		Other consists of Ephemeroptera, spiders, and sowbugs	Beal, 1918
		Diptera	16.09			
		Hemiptera/Homptera	14.58			
		Coleoptera	12.53			
		Lepidoptera	9.39			
		Orthoptera	1.09			
		Odonata	15.1			
		Other	8.09			
Cliff swallow	Throughout United States (N=375)	Ants	8.24		Other consists of Odonata, Ephemeroptera, spiders, and snails	Beal, 1918
		Other Hymenoptera	20.51			
		Diptera	13.95			
		Hemiptera/Homptera	26.32			
		Coleoptera	26.8			
		Orthoptera	0.71			
		Other	2.97			
Barn swallow	27 states and Canada (n=467)	Ants	9.89			Beal, 1918
		Other Hymenoptera	12.82			
		Diptera	39.49			
		Hemiptera/Homptera	15.1			
		Coleoptera	15.63			
		Lepidoptera	2.39			
		Orthoptera	0.51			
		Odonata	4			
Tree swallow	22 states and Canada	Ants	6.37		90% of plant material consumed consisted of	Beal, 1918

TABLE 3-91
Diet Composition of Swallows in North America

Species	Location	Taxa	Percent volume	Percent frequency	Comments	Reference
	(n=343)	Other Hymenoptera	7.58		fruit of waxberry (*Myrica carolinensis*). Other consisted primairily of spiders	
		Diptera	40.58			
		Coleoptera	14.39			
		Lepidoptera	5.02			
		Orthoptera	0.37			
		Odonata	4			
		Other	4.64			
		Plant Material	16.9			
Violet-green swallow	Arizona, California, Oregon, Colorado, Wyoming, and Alaska. (N=110)	Ants	9.42		Other consisted primarily of Ephemeroptera	Beal, 1918
		Other Hymenoptera	17.48			
		Diptera	19.36			
		Hemiptera/Homptera	35.96			
		Coleoptera	10.57			
		Lepidoptera	3.12			
		Other	4.09			
Bank swallow	21 states and Canada (n=394)	Ants	13.39		Other consists of Ephemeroptera (which accounted for 43% of diet in April), spiders, and snails	Beal, 1918
		Other Hymenoptera	20			
		Diptera	26.63			
		Hemiptera/Homptera	7.96			
		Coleoptera	17.9			
		Lepidoptera	2.21			
		Odonata	2.11			
		Other	10.53			

TABLE 3-91
Diet Composition of Swallows in North America

Species	Location	Taxa	Percent volume	Percent frequency	Comments	Reference
	New York	Coleoptera	36.13			Stoner, 1936
	(n=64)	Diptera	31.59			
		Homoptera	17.81			
		Hemiptera	6.13			
		Hymenoptera	5.66			
		Ephemeroptera	1.66			
		Other	1.02			
Northern rough-winged swallow	15 states and Canada	Ants	11.99		Other consists of Odonata, Ephemeroptera, spiders, and snails	Beal, 1918
	(n=136)	Other Hymenoptera	18.91			
		Diptera	32.89			
		Hemiptera/Homptera	14.9			
		Coleoptera	14.83			
		Lepidoptera	1.11			
		Orthoptera	0.12			
		Other	5.04			
		Plant Material	0.21			

TABLE 3-92
Summary of Reproductive Characteristics for North American Swallows

Species	Nest Habitat	Egg Dates	Clutch size	Number of Clutches Per Year	Incubation Period	Nestling Period	Age of First Breeding	References
Purple martin	Tree cavities, multiroom bird houses	May 21-July 13 (New York)	3 to 8, typically 4 to 5	1	16 to 18 days	26 to 31 days	1 year	DeGraaf et al., 1981
Cliff swallow	Mud cups on cliffs, cave entrances, buildings, bridges, culverts	May 20-5, June peak in Nebraska	1 to 6, typically 3 to 4	1	10 to 19 days, typically 13 to 15 days	20 to 26 days	1 year	Brown and Brown, 1995
Barn swallow	Mud cups on human-made structures, especially buildings (barns)	May 11-August 3 (New York)	4 to 6, typically 4 to 5	1 to 2 in warmer areas	Approx. 15 days	16 to 23 days	1 years	DeGraaf et al., 1981
Tree swallow	Tree cavities or nest boxes	Laying starts in early May	2 to 8, typically 4 to 7	1, rarely 2	11 to 19 days, typically 14 to 15 days	15 to 25 days, typically 18 to 22 days	1 year, if possible	Robertson et al., 1992
Violet-green swallow	Tree cavities or nest boxes	May 1-July 1 (California)	4 to 7, typically 4 to 5	1	13 to 14 days	Approx. 23 days	No data	Bent, 1942
Bank swallow	Burrows in earthen banks	May 15-July 13 (New York)	4 to 6, typically 5	Up to 2	14 to 16 days	18 to 22 days	1 year	Stoner, 1936; DeGraaf et al., 1981
Northern rough-winged swallow	Burrows in earthen banks	Mid-May to mid-June	4 to 8, typically 4 to 6	1	15.5 to 16.5 days	17 to 21.5 days	1 year	DeJong, 1996
Cave swallow	Mud cups on cliffs, cave entrances, buildings, bridges, culverts	April-July (New Mexico)	3 to 5, occasionally 1 to 2	2	No data	20 to 23 days	1 yr	West, 1995

3.3.23 Marsh Wren (*Cistothorus palustris*)[1]

The marsh wren (*Cistothorus palustris*) belongs to the order Passeriformes, family Troglodytidae. Wrens are small insectivorous birds that live in a variety of habitats throughout the United States. They have long, slender bills adapted for gleaning insects from the ground and vegetation. Most species are migratory, although some populations are year-round residents. Marsh wrens eat mostly insects, and occasionally snails, which they glean from the surface of vegetation. This species was formerly known as the long-billed marsh wren (*Telmatodytes palustris*).

Distribution

The marsh wren is a common bird inhabiting freshwater cattail marshes and salt marshes. Marsh wrens breed throughout most of the northern half of the United States and in coastal areas as far south as Florida; they winter in the southern United States and into Mexico, particularly in coastal areas.

Body Size and Weight

Although wrens are small (13 cm bill tip to tail tip; about 10 g body weight), males tend to be about 10 percent heavier than females . Body weight varies seasonally; in Georgia, where marsh wrens are resident throughout the year, they tend to be heavier in the spring and summer than in the fall and winter (Kale, 1965). Body weights for marsh wrens from different locations throughout their range are presented in Table 3-93.

TABLE 3-93
Body Weights (g) for the March Wren (*Cistothorus palustris)*

Location	Sex	Mean	Reference
New York	Female-Breeding	10.6 $\pm$ 0.99	Tintle (unpublished)
	Male-Breeding	11.9 $\pm$ 0.72	
Georgia	Female	9.4 $\pm$ 1.1	Kale, 1965
	Male	10.6 $\pm$ 0.7	
	Both	9.4 $\pm$ 1.6	
New York, Minnesota	Nestling		Welter, 1935
	Day-1	1.1	
	Day-3	2.1	
	Day-5	4.7	
	Day-7	6.8	
	Day-9	10.0	
	Day-11	10.6	
	Day-13	11.3	
Georgia	At Fledging	8.84 $\pm$ 0.70	Kale, 1965

[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

Food Habits and Diet Composition

Marsh wrens consume aquatic invertebrates, other insects, and spiders, which they glean from the water surface, on stems and leaves of emergent vegetation, and the marsh floor (Kale, 1965; Welter, 1935). They sometimes also feed by flycatching (Welter, 1935). The insect orders most commonly taken include Coleoptera (both adults and larvae), Diptera (adults and larvae), Hemiptera (juveniles and adults), Lepidoptera (larvae most commonly fed to nestlings); and Odonata (newly emerged) (Bent, 1948; Kale, 1964). When feeding the young, at first the parents bring mosquito adults and larvae, midges, larval tipulids, and other small insects (Welter, 1935). As the young mature, the parents bring larger insects such as ground beetles, diving beetles, long-horned beetles, caterpillars, dragonflies, and sawflies to the nestlings (Welter, 1935). In a population in Georgia, spiders (usually 1 to 3 mm in size, sometimes 12 to 15 mm), small crabs (5 to 7 mm), small snails (1 to 3 mm), and insect eggs also were consumed and fed to nestlings (Kale, 1965). Thus, organisms that are aquatic for all or part of their lives are an important component of the diet of marsh wren adults and nestlings. Food preferences of marsh wrens are summarized in Table 3-94.

TABLE 3-94
Diet Composition of Marsh Wrens (*Cistothorus palustris)*

Location	Prey Taxon	Percent Volume	Reference
Georgia-Salt Marsh			Kale, 1965
Summer	Hyemenptera	17.3[a]	
	Homoptera	13.0	
	Coleoptera	11.6	
	Lepidoptera	14.6	
	Diptera	8.9	
	Hemiptera	5.4	
	Orthoptera	5.6	
	Spiders	15.1	
	Other Arthropods (Crabs, Amphipods)	1.8	
	Molluscs (Snails)	3.5	
	Other (Insect eggs, Undetermined, etc.)	4.5	
Winter	Hyemenptera	12.4	
	Homoptera	40.1	
	Coleoptera	12.6	
	Lepidoptera	2.9	
	Diptera	7.7	
	Hemiptera	10.0	
	Orthoptera	0.8	
	Spiders	6.2	

TABLE 3-94
Diet Composition of Marsh Wrens (*Cistothorus palustris)*

Location	Prey Taxon	Percent Volume	Reference
	Other Arthropods (Crabs, Amphipods)	0.9	
	Molluscs (Snails)	4.0	
	Other (Insect eggs, Undetermined, etc.)	3.3	

[a] percent wet volume; stomach contents

Food Consumption Rate

Food ingestion was estimated by Kale (1965) for captive wrens in Georgia (1155 kcal/kg BW/day or 0.67 g/g BW/day). Free living food ingestion rates for males and females of 0.96 and 0.99 kg/kg BW/day, respectively, can be estimated using Eq. 10 and body weights from Kale (1965). Using Eq. 18 a fresh weight was calculated for males (0.31 kg/kg BW/day) and females (0.32 kg/kg BW/day) assuming a diet of 100 percent insects and a water content of 69 percent (Table 3-4). (Note: If other body weight values are used, then the rate should be recalculated.)

Water Consumption Rate

No literature data were found describing water ingestion by the Marsh wren. Using Eq. 20 and assuming a body weight of 0.11 kg (as calculated from the above table using adult birds) water ingestion is estimated to average 0.12 L/kg BW/day. (Note: If other body weight values are used, then the rate should be recalculated.)

Soil Ingestion

No soil ingestion data was found in the literature. Although marsh wrens are passarines, their foraging habitats and diet (e.g., aquatic insects in marsh areas) are similar to those of mallards. Thus, the reported rate of soil ingestion for mallards (3.3 percent of the diet) may be applicable to marsh wrens.

Respiration Rate

No literature data were located concerning inhalation rates for marsh wrens. Equation 22, although developed for nonpasserine birds, may be used; however, significant uncertainty in the resulting estimate must be acknowledged. Using this equation and a mean body weight of 0.11 kg, the estimated inhalation rate is 0.68 m^3/kg BW/day. (Note: If other body weight values are used, then the rate should be recalculated.)

Metabolism

Kale (1965) estimated free living (880 kcal/kg BW/day) and basal (444 kcal/kg BW/day) metabolic rates for captive wrens. Free living rates of 1209 kcal/kg BW/day for females and 1174 kcal/kg BW/day for males can be estimated using the equation from Nagy (1987) and body weights from Kale (1965).

Habitat Requirements

Marsh wrens inhabit freshwater and saltwater marshes, usually nesting in association with bulrushes, cattails, and sedges or on occasion in mangroves (Welter, 1935; Bent, 1948; Kale, 1965; Verner, 1965). Standing water from several centimeters to nearly a meter is typical of the areas selected (Bent, 1948). Permanent water is necessary to provide a food supply of insects necessary to maintain the birds and as a defense against predation (Verner and Engelsen, 1970). Deeper water and denser vegetation are associated with reduced predation rates (Leonard and Picman, 1987).

Home Range

Marshes smaller than 0.40 ha usually are not used by breeding marsh wrens (Bent, 1948). Average male territory size for a given year and location can range from 0. 006 to 0.17 ha, depending on the habitat and conditions of the year. Also, there is a trend in polygynous populations for polygynous males to defend larger territories than monogamous males or males that end up as bachelors (Verner and Engelson, 1970; Verner, 1964; Kale, 1965).

Population Density

Because the species is polygynous, there may be more females than males inhabiting breeding marshes. Population density varies with the suitability and patchiness of the habitat. Densities as high as 120 adult birds/ha have been recorded (Kale, 1965). In Georgia, Kale (1965) reported 48.3 pairs/ha during the spring in a salt marsh. In Manitoba, males/ha ranged from 3.4-4.3 (Leonard and Picman, 1987).

Population Dynamics/Survival

Clutch size and number of clutches per year vary with latitude and climate. In some populations, marsh wrens commonly destroy eggs and kill the nestlings of other pairs of their own species and other marsh-nesting passerines (Orians and Wilson, 1964; Picman, 1977; Welter, 1935). Fledging success depends strongly on nest location; nests over deeper water are less vulnerable to predation (Leonard and Picman, 1987). Of nests lost to all causes, Leonard and Picman (1987) found 44 percent due to mammalian predators, 27 percent due to other wrens, 11 percent due to weather, 8 percent due to nest abandonment, and 13 percent unknown. The annual mortality of adults is lower than that of first-year birds.). Mean annual mortality is 70 percent for juveniles and 32 percent for adults in a Georgia salt marsh (Kale, 1965). Both sexes of this species usually commence breeding in the first year following hatching (Kale, 1965).

Reproduction/Breeding

Many populations of marsh wren are polygynous, with some males mating with two, occasionally three, females in a season, while the remaining males have one mate or remain bachelors. For example, Leonard and Picman (1987) found 5 to 11 percent bachelor males, 41 to 48 percent monogamous males, 37 to 43 percent bigamous males, and 5 to 12 percent trigamous males in two marshes in Manitoba, Canada. Similarly, Verner and Engelsen (1970) found 16 percent bachelors, 57 percent monogamous, and 25 percent bigamous males in eastern Washington state. In contrast, Kale (1965) found most males to be monogamous through 4 years of study in Georgia.

Males arrive at the breeding marshes before the females to establish territories that include both nest sites and foraging areas (Kale, 1965; Verner, 1965; Welter, 1935). Males build several nests in their territories throughout the breeding season (Kale, 1965; Verner, 1965). The female usually only adds lining material to a nest of her choice, although some may help construct the breeding nest (Kale, 1965). Breeding nests are oblong in shape, with a side opening, and are woven of cattails, reeds, and grasses and lashed to standing vegetation, generally 30 cm to 1 m above standing water or high tide (Bent, 1948; Verner, 1965). Mean clutch size ranges from 4.5 to 6 (Kale, 1965; Verner, 1965; Leonard and Picman, 1987) with 1 to 3 clutches per year (typically 2; Kale, 1965; Verner, 1965). Incubation lasts from 12 to 16 days with means of 13.1 and 15.1 days reported in Georgia and west Washington, respectively (Kale, 1965: Verner, 1965). Young fledge at 10 to 16 days post-hatch.

In Manitoba, Leonard and Picman (1987) reported the mean number of fledglings per successful nest to be 4.5 in fresh-mixed marshes and 5.1 in fresh cattail marshes. After fledging, one or both parents continue to feed the young for about 12 days (Verner, 1965). In the more monogamous populations, both parents regularly feed young, but in the more polygynous ones, the females may provide most of the food, with males assisting only toward the end of the nestling period (Leonard and Picman, 1988; Verner, 1965).

Behavior and Social Organization

Marsh wrens are year-round residents in some southern and coastal maritime regions where marshes do not freeze. Most migratory wrens breed throughout the northern half of the United States through southern Canada and winter in Mexico and the southern half of the United States (Bent, 1948; Verner, 1965; American Ornthologists' Union, 1983; National Geographic Society, 1987). Weter (1935) reported fall migration in New York as beginning in September and ending in late October while spring migration in New York and Minnesota began in April and ended in May. Eastern Washington had spring migration peaks in mid-March, whereas wrens in western Washington are nonmigratory (Verner, 1965).

3.3.24 American Robin (*Turdus migratorius*)[1]

American robins (*Turdus migratorius*) belong to the order Passeriformes, family Muscicapidae, subfamily Turdinae. Thrushes are common, medium-sized birds that eat worms, insects, and fruit. They live in a variety of habitats, including woodlands, swamps, suburbs, and parks. Most thrushes build nests of mud and vegetation on the ground or in the crotches of trees or shrubs; bluebirds nest in holes in trees and posts or in nest boxes. This group forages primarily on the ground and in low vegetation by probing and gleaning. Some thrushes are neotropical migrants while others reside year-round in North America. Thrushes range in size from the eastern and western bluebirds (18 cm from bill tip to tail tip) to the American robin (25 cm). Male and female plumages are similar in most thrushes, although in some species, such as the bluebirds, the males are more brightly colored.

Distribution

The American robin occurs throughout most of the continental United States and Canada during the breeding season and winters in the southern half of the United States and in Mexico and Central America. The breeding range of the robin has expanded in recent times

[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

with the increasing area covered by lawns and other open habitats (Howell, 1942; Martin et al., 1951; James and Shugart, 1974).

Body Size and Weight

The sexes are similar in size and appearance. Their size varies slightly geographically; the smallest robins are found in the eastern United States and along the Pacific coast, and the largest ones occur in the Rocky Mountains, northern Great Plains, and northern deserts (Aldrich and James, 1991). The size of robins tends to increase with latitude in eastern North America but does not in western North America (Aldrich and James, 1991). Fledglings attain adult size at approximately 6 weeks of age (Howell, 1942). Body weights for American robins from different locations throughout their range are presented in Table 3-95.

TABLE 3-95
Body Weights (g) for the American Robin (*Turdus migratorius)*

Location	Sex	Mean	Reference
Pennsylvania	Both	77.3 + 0.36	Clench & Leberman, 1978
New York	Male-Nonbreeding	86.2 ± 6.1	Wheelwright, 1986
	Female-Nonbreeding	83.6 ± 6.4	
New York	Male-Breeding	77.4	
	Female-Breeding	80.6	Wheelwright, 1986
New York	Nestlings:		Howell, 1942
	At Hatching	4.1-6.7	
	Day-2	8.4-17.5	
	Day-4	17.9-32.3	
	Day-6	32.5-45.9	
	Day-8	42.0-59.3	
	Day-10	49.0-63.2	
	Day-14	51.8-58.2	

Food Habits and Diet Composition

Robins forage by hopping along the ground in search of ground-dwelling invertebrates and by searching for fruit and foliage-dwelling insects in shrubs and low tree branches (Malmborg and Willson, 1988; Paszkowski, 1982). In the months preceding and during the breeding season, robins feed mainly (greater than 90 percent volume) on invertebrates and on some fruits; during the remainder of the year, their diet consists primarily (over 80 to 99 percent by volume) of fruits (Martin et al., 1951; Gochfeld and Burger, 1984; Wheelwright, 1986). Robins eat a wide variety of both plant and animal foods; in a compilation of diet records collected throughout the United States and southern Canada, Wheelwright (1986) found that robins consumed fruits from 51 genera and invertebrates from 107 families. Commonly eaten fruits include plums, dogwood, summac, hackberries, blackberries, cherries, greenbriers, raspberries, and juniper (Martin et al., 1951; Wheelwright, 1986); common invertebrates include beetles, caterpillars, moths, grasshoppers, spiders, millipedes, and earthworms (Martin et al., 1951; Wheelwright, 1986; Paszkowski, 1982). Wheelwright (1986) has compiled seasonal changes in the proportion of plants and invertebrates consumed by robins in three different sections of the United States. Wheelwright (1986) also has summarized the average occurrence of fruits of various plant families in the stomachs of robins by month for these sections. Martin et al. (1951) have summarized the occurrence of fruits of various plant families in more specific areas of the United States.

Wheelwright (1986) found no differences between the sexes in the proportion or types of invertebrates and fruits eaten. Very young robins (up to at least 35 days of age) feed almost entirely on insects and other invertebrates (Howell, 1940). Older juveniles tend to eat a higher proportion of fruit and easy-to-capture prey than adults (Gochfeld and Burger, 1984; Wheelwright, 1986). In a given area, robins often show food preferences: a population in central New York seemed to prefer northern arrowwood and spice bush fruits over most other plants (Wheelwright, 1988); in Illinois, a group ate predominantly frost grapes and Virginia creeper in the late summer and fall (Malmborg and Willson, 1988). Food preferences of American robins are summarized in Table 3-96.

TABLE 3-96
Diet Composition of American Robins (*Turdus migratorius*)

Location	Prey Taxon	Percent Volume	Reference
New York-Forest	Nestling/Fledglings:		Howell, 1942
	Earthworms	15.0[a]	
	Sowbugs	1.7	
	Spiders	2.3	
	Millipedes	3.1	
	Short-Horned Grasshoppers	4.9	
	Beetles	11.6	
	Lepidopteran Larvae	24.7	
	Ants	3.2	
	Unidentified Animal	5.2	
	Grass (All Parts)	19.5	
	Mulberries	3.2	
	Honeysuckle Seeds	2.4	
	Unidentified Plants	4.2	
Eastern United States	Adults:		Wheelwright, 1986
Spring	Fruit	7[b]	
	Invertebrates	93	

TABLE 3-96
Diet Composition of American Robins (*Turdus migratorius*)

Location	Prey Taxon	Percent Volume	Reference
Summer	Fruit	68	
	Invertebrates	32	
Fall	Fruit	92	
	Invertebrates	8	
Winter	Fruit	83	
	Invertebrates	17	
Central United States			Wheelwright, 1986
Spring	Fruit	8 [b]	
	Invertebrates	92	
Summer	Fruit	41	
	Invertebrates	59	
Fall	Fruit	76	
	Invertebrates	24	
Winter	Fruit	73	
	Invertebrates	27	
Western United States			Wheelwright, 1986
Spring	Fruit	17 [b]	
	Invertebrates	83	
Summer	Fruit	29	
	Invertebrates	71	
Fall	Fruit	63	
	Invertebrates	37	
Winter	Fruit	70	
	Invertebrates	30	

[a] percent wet weight; stomach contents
[b] percent volume; stomach contents

Food Consumption Rate

During seasons when fruits dominate the diet, robins may need to consume quantities in excess of their body weight to meet their metabolic needs each day. Robins as well as other fruit-eating birds exhibit a low digestive efficiency for fruits; Karasov and Levey (1990) estimated the metabolizable energy coefficient (MEC) (i. e., the proportion of food energy that actually is assimilated) for robins eating a mixed fruit diet to be only 55 percent, perhaps because of the low retention time of the digested matter in the gut (Levey and

Karasov, 1992). The short retention time might actually be an adaptation to eating fruit because large quantities of fruit must be processed to obtain an adequate protein intake. In contrast, when eating insects, robins (as well as other bird species) exhibit a higher digestive efficiency of approximately 70 percent (Levey and Karasov, 1989). Moreover, the energy content of insects tends to be higher than that of most fruits, particularly on a wet-weight basis. Thus, during the spring when robins are consuming insects, they should consume a smaller amount relative to their body weight than when eating fruits.

A food consumption rate of 1.52 g/g BW/day was estimated by Hazelton et al. (1984) for free-living robins in Kansas. Skorupa and Hothem (1985) reported an ingestion rate of 0.89 g/g BW/day for birds in California. Using Eq. 10 an ingestion rate of 0.02 kg/kg BW/day was estimated assuming a body weight of 0.081 kg (as calculated from the above table using adult birds). Equation 18 was then used to determine a fresh weight rate of 0.1 kg/kg BW/day assuming a summer diet of 68 percent fruit and 32 percent invertebrates (Wheelwright, 1986) and respective water contents of 77 percent and 84 percent (Table 3-4). (Note: If other body weight values are used, then the rate should be recalculated.)

Water Consumption Rate

No data concerning water consumption for American robins were available in the literature. A water ingestion rate for the robin of 0.14 L/kg BW/day can be estimated using the Eq. 20 and a mean body weight from Clench and Leberman (1978). (Note: If other body weight values are used, then the rate should be recalculated.)

Soil Ingestion

No information concerning soil ingestion in American robins could be found in the literature. Both robins and woodcocks consume earthworms; however, earthworms comprise >60 percent and up to 99 percent of the American woodcock diet (Sperry, 1940; Krohn, 1970); Stribling and Doerr, 1985) compared to <20 percent of the American robin diet (Howell, 1942). Therefore, the soil ingestion rate of 10.4 percent or the diet reported for American woodcocks (Beyer et al., 1994) is likely to be an extreme upperbound for the robin. If the soil ingestion rate is proportioned to the percent of earthworms in the diet, then soil would only make up 2.1 percent of the robin diet.

Respiration Rate

No data concerning respiration rates in robins could be found in the literature. Using Eq. 22 and a mean body weight of 0.081 kg, a respiration rate of 0.73 m^3 air/kg BW/day was estimated. (Note: If other body weight values are used, then the rate should be recalculated.)

Metabolism

Hazelton et al. (1984) estimated a metabolic rate of 344 kcal/kg BW/day for the American robin using equations from Kendeigh (1969). Basal and free-living metabolic rates of 259 and 713 kcal/kg BW/day, respectively can be estimated using the equations from Lasiewski and Dawson (1967) and Nagy (1987), respectively. Both estimates used body weights from Clench and Liberman (1978). Recently, Nagy, et al. (1999) estimated a field metabolic rate for the American robin of 16.9 kcal/day (71.3 KJ/day).

Habitat Requirements

Access to fresh water, protected nesting sites, and productive foraging areas are important requirements for breeding robins (Speirs, 1953). Breeding habitats include moist forests, swamps, open woodlands, orchards, parks, and lawns. Robins forage on the ground in open areas, along habitat edges, or the edges of streams; they also forage above ground in shrubs and within the lower branches of trees (Paszkowski, 1982; Malmborg and Willson, 1988). Nests in wooded areas are usually near some type of opening such as the forest edge or a treefall gap (Young, 1955; Knupp et. al., 1977). During the nonbreeding season, robins prefer moist woods or fruit-bearing trees and shrubs (Robbins et al., 1983). In the fall, flocks of migratory robins are often found along forest edges or clearings where fruits are most plentiful (Baird, 1980).

Home Range

During the breeding season, male robins establish breeding territories, which the female helps to defend against other robins. Nonetheless, the territories of different pairs often overlap where neither pair can establish dominance (Young, 1951). Most foraging during the breeding season is confined to the territory, but adults sometimes leave to forage in more productive areas that are shared with other individuals (Howell, 1942; Young, 1951; Pitts, 1984). In some prime nesting areas (e. g., dense coniferous forest), where robin densities are high, territories are small and the birds might often forage elsewhere (Howell, 1942). Adult robins often return to the same territory in succeeding years (Young, 1951). During the nonbreeding roosting period, robins are likely to return to the same foraging sites for many weeks and to join roosts within 1 to 3 km of these foraging areas (Morrison and Caccamise, 1990). Pitts (1984) estimated mean territory size during spring in Tennessee to be 0.42 ha. In New York, estimates were 0.11 ha in dense conifers and 0.21 ha in unspecified forest (Howell, 1942).

Population Density

Nesting population density varies with habitat quality. Densely forested areas that provide well-protected nest sites have been found to support high densities of nesting robins; however, the relatively small territories found in these areas might not be used as much for foraging as those containing open areas (Howell, 1942). Wintering robins are most common in pine or oak pine communities of the southeastern and southcentral United States, and decrease in abundance in drier, less forested areas westward (Speirs, 1953). Population densities have been estimated at 8.6 pairs per hectare in Tennessee during the spring (Pitts, 1984). In New York, dense conifers supported 8.6 pairs/ha and 4.9 pairs/ha in unspecified forest (Howell, 1942).

Population Dynamics/Survival

Robins first attempt to breed the year after they hatch (Henny, 1972) and will raise multiple broods in a season (Howell, 1942). Predation is often a major source of mortality for both eggs and nestlings (Knupp et al., 1977; Klimstra and Stieglitz, 1957). Approximately half of the adult birds survive from year to year (Farner, 1949; Henny, 1972); the average longevity of a robin that survives to its first January is from 1.3 to 1.4 years (Farner, 1949). Annual mortality was reported as 51 percent for adults and 78 percent for juveniles in North America (Henny, 1972).

Reproduction/Breeding

The onset of the breeding season is later at higher latitudes (approximately 3 days for each additional degree in the east) and altitudes, but mating and egg laying generally occur in April or May (James and Shugart, 1974; Knupp et al., 1977). Males arrive on the breeding grounds before females to establish territories; females pair with established males, usually for the duration of the breeding season (Young, 1951). The female primarily builds the nest out of mud, dried grass, weedy stems, and other materials, constructing it on horizontal limbs, tree-branch crotches, within shrubs, or on any one of a number of man-made structures with horizontal surfaces (Howell, 1942; Klimstra and Stieglitz, 1957).

First clutches usually contain three or four eggs; later clutches tend to contain fewer eggs (Young, 1955). The female does all of the incubating, which continues for 10 to 14 days following the laying of the second egg (Klimstra and Stieglitz, 1957; Young, 1955). Both males and females feed the nestlings (Young, 1955). Chicks fledge at about 13 days (Young, 1955). Following fledging, the brood often divides, with the male and female each feeding half of the fledglings for another 2 weeks (Weatherhead and McRae, 1990). Females may start another brood before the current one is independent, leaving the male to feed all of the fledglings (Young, 1955). After reaching independence, juveniles often form foraging flocks in areas of high food availability (Hirth et al., 1969). Average number of fledglings per successful nest was reported as 2.9 by Young (1955) in Wisconsin. In Maine, Knupp et al. (1977) reported 2.5 fledglings per successful nest.

Behavior and Social Organization

Most robins nesting in the northern United States and Canada winter in the Gulf Coast States and the Carolinas (Speirs, 1953; Dorst, 1962, as cited in Henny, 1972). Wintering robins are most abundant between 30 and 35 °N latitude (Speirs, 1953). Robin flocks migrate during the day (Robbins et al., 1983); most northern robins leave their breeding grounds from September to November and return between February and April (Howell, 1942; Young, 1951; Fuller, 1977). Fall migration through Minnesota was reported to begin in mid-September, peak in mid-October and end in early November (Fuller, 1977). Spring migration arriving in New York began in February and ended in March (Howell, 1942) while spring migration into Wisconsin began in mid-March and ended in mid-April (Young, 1951).

In the nonbreeding season, robins often join single-or mixed-species roosts that can include tens of thousands of birds (Morrison and Caccamise, 1990). Early in the breeding season, robins often roost communally. Males can continue to use these roosts throughout the breeding season, whereas females stop once they begin incubating eggs (Howell, 1940; Pitts, 1984). As fall approaches and their diet turns more toward fruits, robins in many areas begin to roost communally again and may join other species, such as common grackles and European starlings, in large roosts (Morrison and Caccamise, 1990).

3.3.25 Red-Winged Black Bird (Agelaius phoeniceus)[3]

The red-winged black bird is in the order Passeriformes, family Emberizidae. It is one of the most abundant birds in North America and has been widely studied. There are

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[3] New species accounts compiled for ARAMS.

26 sub-species, which are distinguished primarily by size, plumage, and morphological differences. The status of several of these sub-species is questionable due to the high degree of overlap among populations, extensive dispersal and lack of breeding barriers. In addition, several of the subspecies have not been clearly differentiated genetically (Yasukawa and Searcy, 1995).

Distribution

Red-winged black birds are common and widespread throughout North America. The breeding range extends from southern Alaska and central Canada south into Central America and from California to the Atlantic coast. Throughout the majority of the range they are year-round residents, but the northern populations migrate into the southern portions of the range during the winter months (Yasukawa and Searcy, 1995).

Body Size and Weight

Red-winged blackbirds are approximately 22 cm long. The average adult male is 70.5 g and is nearly twice as large as the average adult female that weighs 43.8 g. Throughout the year the body mass varies considerably, being greatest immediately prior to the start of the breeding season and lowest at the end of the breeding season. The postnatal growth rate of red-winged blackbirds is among the highest reported among bird species. Hatchlings weigh an average of 3.47 ± 0.84 SD g and increase their body weights 8-11 fold within 10 days (Olson, 1992).

TABLE 3-97
Body Weights (g) for the Red-Winged Black Bird (*Agelaius phoeniceus)*

Location	Age	Sex	Mean	Reference
Ohio	Fledgling	Male	35.8	Olson, 1992
		Female	29.3	
	Yearling	Male	60.0	Holcomb and Twiest, 1968
		Female	41.6	
	Adult	Male	70.5	
		Female	43.8	

Food Habits and Diet Composition

Red-winged blackbirds forage in a wide variety of habitat types including marshes, grasslands, lakeshores, pastures, and agricultural fields. They frequently forage on the ground and, during the non-breeding season, are associated with large mixed-species flocks (Yasukawa and Searcy, 1995).

During the non-breeding season, the primary food source is vegetable matter with lesser amounts of animal matter. During the breeding season, animal matter comprises a much greater proportion of the diet, especially for birds in non-agricultural areas. The principle food items consumed by red-winged blackbirds during the winter in Tennessee were corn (38 percent) and weed seeds (36 percent), with smaller amounts of sorghum and wheat seeds, trees seeds, and insects (Dolbeer et al., 1978). Birds in Ohio consumed 92.4 percent plant matter, of which 70.8 percent was corn, and 7.6 percent animal matter, of which 7.5 percent was arthropods (Williams and Jackson, 1981). In North Dakota, plant matter accounted for as much as 98 percent of the diet, with insects accounting for the remaining 2 percent. Sunflower seeds accounted for 43-73 percent of the plant matter in the diet. During the breeding season insects may account for 50-85 percent of the dietary intake for red-winged black birds (McNicol et al., 1982).

Food Consumption Rate

There is no data found in the literature for food consumption rates for wild populations of red-winged blackbirds. Captive males were found to have average food intakes between 0.55 and 0.65 kcal/g BW/day (Brenner and Hayes, 1985). Captive birds in an experimental study were found to consume approximately 13 g of feed per day (Robizon and Katz, 1980). Using the mean body weight of the red-winged blackbirds in the study, the daily food consumption rate is 0.20 kg/kg BW/day. Using Eq. 10 and assuming a mean body weight of 0.057 kg (as calculated using adult body weights in table 3-97), a food consumption rate of 0.022 kg/kg BW/day can be estimated. A fresh weight (0.12 kg/kg BW/day) can be estimated assuming a diet of 70 percent seeds and 30 percent other plant matter with respective water contents of 9.3 and 85 percent (Table 3-4). (Note: if using different body weights, then the rate should be recalculated.)

Water Consumption Rate

Wild populations frequently nest over or near water, but occasionally may be as far as 4.8 km from a water source (Miller, 1968). Birds in the wild often were observed drinking after foraging on seeds and agricultural grains (Yasukawa and Searcy, 1995). Captive populations have been reported to drink 0.03-0.28 L water/kg BW/day. Robizon and Katz (1980) reported a water consumption rate of approximately 37 mL per bird per day (0.56 L/kg BW/day using the mean body weight from the study of 0.0658 kg). Water consumption appears to vary among subspecies, suggesting different ecological adaptations, but in general water consumption increases with increasing temperatures and longer photoperiods (Brenner and Hayes, 1985). Using Eq. 20 and a body weight of 0.057 kg, a water consumption rate of 0.15 L/kg BW/day can be calculated. (Note: if using different body weights, rate should be recalculated.)

Soil Ingestion

No data concerning soil consumption rates in red-winged blackbirds was available in the literature reviewed. Both red-winged blackbirds and wild turkeys forage on the ground for seeds and other plant material; therefore it is likely that the soil ingestion rate of 9.3 percent of the diet presented for wild turkeys in Beyer et al. (1994) is representative of that for red-winged blackbirds. However, it should be noted that 9.3 percent is likely an upperbound value and therefore, its use would be very conservative.

Respiration Rate

Thompson et al. (1981) reported that recently fed birds had a respiration rate of 56.53 respirations/minute, while birds with empty stomachs had respiration rates of 79.17 respirations/minute. A respiration rate can be calculated using Eq. 22, though this equation is for nonpasserine birds and applicability for estimating inhalation rates of passerines is not known. Using this equation an estimate of 0.79 m^3/kg BW/day can be calculated. (Note: if using different body weights, rate should be recalculated.)

Metabolism

Red-winged black birds are sexually dimorphic in terms of metabolism; adult males have a reduced metabolic rate relative to adult females. Lewies and Dyer (1969) found the daytime metabolic rates to be 14.44 cal/g-h for adult males and 14.60 cal/g-h for females. They reported the night metabolic rates to be 9.41 and 11.83 cal/g-h for males and females respectively. Respiratory quotients (CO_2 produced/O_2 consumed per unit time) were also significantly different between the sexes (males 0.75 and females 0.79; Yasukawa and Searcy, 1995). Resting metabolic rates for nestlings was reported at 3.13 ± 0.22 SD cm^3 O_2/g/h (Olson, 1994) and RMR for adult males 2.54 ± 0.14 SD cm^3 O_2 /g/h and adult females 2.93 ±0.17 SD cm^3 O_2/g/h (Olsen, 1992).

Habitat Requirements

A variety of natural and human habitats are used by red-winged blackbirds. They are primarily associated with large freshwater wetlands and prairies, but red-winged blackbirds will also use saltwater marshes, roadside ditches, agricultural fields, pastures, suburban areas, and urban parks. Roosting habitats are generally found in areas with dense vegetative cover. Nests are often woven among vertical shoots or branches over water, and may be located on or near the ground in upland habitats (Yasukawa and Searcy, 1995).

Home Range

Individuals in Arkansas and Texas are reported to forage as far as 80 km from their roost sites (Meanly, 1965) and individuals in California were found to range as far as 32 km from their roost sites (Orians, 1961). White et al. (1985) found that the average daily flight distance away from the roost site was 14 km. During the breeding season, the males establish and defend distinct territories that range in size depending largely on habitat characteristics. The average territory established in wetland habitats was 1,625 m^2 and 2,895 m^2 (0.16 and 0.29 ha, respectively) in upland habitats (Seary and Yasukawa, 1995).

Population Density

Population density is variable depending on type and size of habitat as well as the presence of competitive species such as the yellow-headed blackbird. Generally, large freshwater wetlands support the highest population densities, and areas such as roadside ditches support the lowest population densities. Estimates of population densities for a variety of habitats are presented in Table 3-98.

Population Dynamics/Survival

Breeding for both sexes appears to begin in the second year of life. Dyer et al. (1977) presented data on lifetime reproductive success for red-winged blackbirds. They also estimated that between 40.1 and 80.0 percent of the eggs successfully hatch, and of those, 40-88 percent of the nestlings survive to leave the nest. An estimated 0.58 to 4.20 fledglings survive per successful nest and the overall average is between 0.55 and 1.96 fledglings per nesting attempt. The female initiates an average of 1.7 nesting attempts per season.

Renesting is common following nest failure, however, only 3.8 percent of female red-winged blackbirds successfully produce a second brood (Yasukawa and Searcy, 1995). The longevity record for a red-winged blackbird is 15 years, nine months (USGS Bird Banding Laboratory, May 2000), but the average life expectancy is 2.14 years (Dyer et al., 1977; Searcy and Yasukawa, 1981). The adult survival rate is between 42.1 and 62.0 percent (Fankhauser, 1967) and the mean age between 0.94 and 1.92 years (Dyer et al., 1977).

TABLE 3-98
Average Population Density Estimates for the Red-Winged Blackbird (*Agelaius phoeniceus)* in Different Habitat Types

Habitat Type	Avg No. males/ha	Avg No. Females/male	Reference
Wetland w/ yellow-headed blackbird	2.5	2.2	Vierling, 1999
	8.5		Orians, 1980
Wetland w/o yellow-headed blackbird	0.34		Nelms et al., 1994
	1.08		Besser, 1985
	2.82	2.4	Vierling, 1999
	9.6		Weatherhead and Robertson, 1977
	14.5		Case and Hewitt, 1963
	30.3		Nero, 1956a
Tallgrass Prairie	0.31	1.9	Vierling, 1999
Hayfields	0.006		Nelms et al., 1994
	0.16	1.9	Vierling, 1999
	0.34		Besser, 1985
	1.8		Case and Hewitt, 1963
Roadside and railroad ditches	0.04		Nelms et al., 1994
	0.21	2.2	Vierling, 1999
	0.55		Basser, 1985

Reproduction/Breeding

Breeding behavior begins in March and extends through May, with a general trend for earlier breeding in the more southern populations. Red-winged blackbirds are polygamous, and a single male may have as many as 15 females within its breeding territory, however, extra pair mating is common. The mean clutch size varies between 2.43 and 3.7 eggs, with a total mean clutch size of 3.28 eggs (Yasukawa and Searcy, 1995). Incubation periods range between 11 and 13 days with the average being 12.6 days (Nero, 1984; Martin, 1995). Brooding and rearing is done solely by the female.

Behavior and Social Organization

During the breeding season, red-winged black birds are highly territorial and the males will spend much of their time guarding and actively defending their territory (Orians, 1961). Territoriality is marked by conspicuous behavior such as song and visual displays, as well as aggressive responses to persistent intruders (Nero, 1956b; Peek, 1972). There appears to be some dominance status among females within a breeding territory, influenced by the order of settlement and proximity to the male (Roberts and Searcy, 1988). During the non-breeding season, red-winged black birds are highly gregarious, and will join large multi-species flocks for roosting and foraging. Also, during the non-breeding season, they begin activity at sunrise and spend the day foraging, preening, and resting; returning to the roost about two hours before sunset (Smith and Bird, 1969).

3.3.26 Western Meadowlark (*Sturnella neglecta*)[2]

The western meadowlark is in the order Passeriformes, family Emberizidae. This bird is one of the most abundant and widely distributed birds in North America. It is similar in appearance to the eastern meadow lark (*Sturnella magna*), differing only in song (Lanyon 1994).

Distribution

Western meadowlarks range throughout western North America, west of the Mississippi River to the Pacific Coast (Lanyon, 1994). They occur from the southern half of British Columbia, Alberta, Saskatchewan, and Manitoba in the north, to central Mexico in the south.

Body Size and Weight

The western meadowlark is a medium-sized terrestrial songbird, approximately 24 cm in length (National Geographic Society, 1987) with a long, slender bill, short tail, and long legs (Lanyon, 1994). Males meadowlarks weigh more than females. Body weights for western meadowlarks from different locations throughout their range are presented in Table 3-99.

TABLE 3-99
Body Weights (g) for the Western Meadowlark (*Sturnella neglecta)*

Location	Sex	N	Mean	Reference
South Dakota	Male	3[a]	111.9±2.2[b]	Wiens and Rotenberry, 1980
	Female	3[a]	86.3±3.0[b]	
Texas	Male	3[a]	110.9±3.0[b]	
	Female	3[a]	90.1±1.1[b]	
Washington	Male	4[a]	113.2±1.5[b]	
	Female	4[a]	94.2±3.5[b]	
Nevada	Male	3	111.5±0.8	
Saskatchewan	NS[c]	NS	103	Wiens and Innis, 1974
Colorado	NS	NS	110	

[a] Number of sampling dates
[b] mean ± standard deviation of means for n sampling dates
[c] Not stated

2 Text directly from Sample et al. (1997a).

Food Habits and Diet Composition

Western meadowlarks are ground foragers that consume both plant material (primarily seeds) and invertebrates (Bent, 1958; Lanyon, 1994; Rotenberry, 1980). Bent (1958) reports the diet to consist of approximately 30 percent plant and 70 percent insect foods. Food preferences of western meadowlarks are summarized in Table 3-100. The mean size of insects consumed by western meadowlarks in Washington ranges from 7.7 to 14.6 mm (Rotenberry, 1980).

TABLE 3-100
Diet Composition of Western Meadowlarks (*Sturnella neglecta)*

Location	Prey Taxon	Percent Volume	Reference
Throughout North America (n=1920)	Plant material	36.7	Lanyon, 1994
	Grain	30.8	
	Weed seeds	5.3	
	Miscellaneous	0.6	
	Arthropods	63.3	
	Coleoptera	21.3	
	Orthoptera	20.3	
	Lepidoptera	12.2	
	Hemiptera	1.7	
	Hymenoptera	5.6	
	Diptera	0.1	
	Arachnida	0.2	
	Miscellaneous insects	1.9	
Washington (n=23)[a]	Angiospermae		Rotenberry, 1980
	Graminae	1.6	
	Miscellaneous forbs	0.3	
	Arachnida		
	Araneida	0.7	
	Solpugida	0.6	
	Insecta		
	Coleoptera		
	Curculionidae	14.8	
	Tenebrionidae	14.4	
	Scarabidae	5.2	
	Carabidae	7.6	
	Larvae	0.6	

TABLE 3-100
Diet Composition of Western Meadowlarks (*Sturnella neglecta)*

Location	Prey Taxon	Percent Volume	Reference
	Miscellaneous	0.8	
	Hymenoptera		
	Formicidae	2.1	
	"Wasps"	1.5	
	Lepidoptera		
	Larvae	10.3	
	Diptera		
	Asilidae	0.4	
	Miscellaneous	0.3	
	Neuroptera	0.8	
	Hemiptera	1.1	
	Orthoptera	29.6	
	Homoptera		
	Cicadidae	7.4	
	Miscellaneous	0.3	

[a] Values represent means from 4 sampling dates

Food Consumption Rate

Bryant (1914, cited in Lanyon, 1984) estimates that daily food consumption by western meadowlarks is approximately three times its stomach capacity. Mean dry mass per stomach in Washington ranges from 0.35 to 1.3 g (mean±STD: 0.79±0.40; Rotenberry, 1980). Assuming a body weight of 108.8 g and a diet consisting almost exclusively of insects (Rotenberry, 1980) with a water content of 76.3 percent (Bell, 1990), the mean daily food ingestion by western meadowlarks is estimated to be 0.028±0.014 g/g/d. This estimate is comparable to that obtained using Eqs. 19 and 20: 0.026 g/g/d (assuming body weight=108.8 g, diet=100 percent insects, water content= 76.3 percent).

Water Consumption Rate

Pierce (1974) reports *ad libitum* water consumption by western meadowlarks to be 18.6 percent of their body weight per day (0.186 L/kg/d). Minimum water consumption for weight maintenance was 66 percent of the *ad libitum* rate. This is equivalent to that estimated using Eq. 20 and assuming a body weight of 108.8 g (0.12 L/kg BW/d).

Soil Ingestion

Western meadowlarks are reported to ingest grit, probably to aid in digestion or as a source of inorganic nutrients (Gionfriddo and Best, 1996). Grit was observed in 44 percent of the stomachs considered. The mean particle size in stomachs of adults was 1.4 mm with 2–3 particles/stomach (Gionfriddo and Best, 1996). Data relating grit ingestion to food ingestion rate were not found in the literature, however. Consequently, estimation of a soil ingestion rate from these data is problematic.

Respiration Rate

No literature data were located concerning inhalation rates for western meadowlarks. Eq. 22, although developed for nonpasserine birds, may be used; however, significant uncertainty in the resulting estimate must be acknowledged.

Metabolism

Nocturnal and diurnal resting metabolic rates for western meadowlarks are 1.73 and 1.97 mL O_2 /g/h, respectively (Pierce, 1974). These values are low relative to other birds and represent adaptations to hot, open environments.

Habitat Requirements

Western meadowlarks are common in open habitats including native grasslands, pastures, hay and alfalfa fields, weedy borders, cropland, roadsides, orchards, and, occasionally, desert grasslands (Lanyon, 1994). In areas where their ranges overlap, western meadowlarks generally prefer more arid habitats than eastern meadowlarks (Lanyon, 1956; National Geographic Society, 1987).

In an extensive study of habitat associations and avian communities in a shrub-steppe environment in Washington, Wiens and Rotenberry (1981) found western meadowlarks to be broadly distributed over most of the available habitat. While the density of meadowlarks did not correlate well with overall habitat variation, density was positively correlated with sagebrush, grass, and litter cover and negatively with bare ground.

Home Range

Male western meadowlarks defend multipurpose territories in which they forage, breed, and raise young (Lanyon, 1994). Territories in Wisconsin varied from 1.2 to 6.1 ha but were generally 2.8 to 3.2 ha. Kendeigh (1941) reports territories to range from 4 to 13 ha in Iowa. Schaef and Picman (1988) report a mean territory size of 7 ha in Manitoba.

Population Density

Wiens and Rotenberry (1981) report densities of western meadowlarks in shrub-steppe habitat in Washington ranging from 0.02 to 0.88 individuals/ha. In an Iowa prairie, Kendeigh (1941) observed approximately 0.05 birds/ha. In a state-wide census of breeding birds in North Dakota, Stewart and Kantrud (1972) estimated the mean density of western meadowlarks to be 0.11 pairs/ha.

Population Dynamics/Survival

In good habitat, western meadowlarks can be very abundant. Stewart and Kantrud (1972) estimate western meadowlarks to be the fourth most abundant breeding bird in the North Dakota (behind horned larks, chestnut-collared longspur, and red-winged blackbirds). The state-wide population was estimated to be over 2×10^6 pairs. Although the longevity of captive birds ranges from 3 to 5 years, some individuals have lived as long as 10 years (Lanyon, 1994). Survivorship in wild populations is unknown.

Reproduction/Breeding

Data on reproduction in western meadowlarks was derived from Bent (1958) and Lanyon (1994). Western meadowlarks make well-concealed nests on the ground, often in a shallow depression and frequently in thick vegetation. Eggs may be present from April to July, throughout the range. Clutch sizes range from 3 to 6 eggs but average 4.8 eggs. Incubation lasts 13 to 14 days, rarely 15 to 16 days. A hatching success of 53 percent has been reported in British Columbia. The nestling period lasts 10 to 12 days. Western meadowlarks may raise up to two clutches/year. Sexual maturity is reached in one year.

Behavior

Although western meadowlarks will tolerate other ground-nesting species in their territories, they aggressively defend against both conspecifics and eastern meadowlarks (in areas where both species are sympatric; Lanyon, 1994).

Social Organization

During fall and winter, western meadowlarks form loose flocks of up to 200 individuals. The flocks may include eastern meadowlarks (Lanyon, 1994).

3.4 Reptiles and Amphibians

3.4.1 Snapping Turtle (*Chelydra serpentina*)[1]

Snapping turtles are in the order Testudines, Family Chelydridae. Snapping turtles are among the largest of the freshwater turtles. They are characterized by large heads with powerful hooked jaws. There are only two species of this family in North America (the snapping turtle, including both the common and Florida snapping turtles, and the alligator snapping turtle).

Distribution

The snapping turtle is primarily aquatic, inhabiting freshwater and brackish environments, although they will travel overland (DeGraaf and Rudis, 1983; Ernst and Barbour, 1972; Smith, 1961). There are two subspecies recognized in North America that are primarily distinguished by range: *C. s. serpentina* (the common snapping turtle, which is the largest subspecies, primarily occupies the United States east of the Rockies, except for the southern portions of Texas and Florida), and *C. s. osceola* (the Florida snapping turtle, found in the Florida peninsula) (Conant and Collins, 1991). In this profile, studies refer to the *serpentina* subspecies unless otherwise noted.

Body Size and Weight

Adult snapping turtles are large, 20 to 37 cm in carapace length, and males attain larger sizes than females (Congdon et al., 1986; Ernst and Barbour, 1972; Galbraith et al., 1988). In a large oligotrophic lake in Ontario Canada, adult males averaged over 10 kg, whereas the females averaged 5.2 kg (Galbraith et al., 1988). In other populations, the difference in size between males and females often is less (Congdon et al., 1986; Galbraith et al., 1988; Hammer, 1969). They reach sexual maturity at approximately 200 mm in carapace length (Mosimann and Bider, 1960). The cool, short activity season in more northern areas results in slower growth rates and longer times to reach sexual maturity (Bury, 1979).

TABLE 3-101
Body Weights (kg) of the Snapping Turtle (*Chelydra serpentina*)

Location	Sex	Mean	Reference
Ontario, Canada/large oligotrophic lake	Adult male (summer)	10.5±2.85 SD	Galbraith et al., 1988
	Adult female (summer)	5.24±0.85 SD	
	Juvenile (both) (summer)	1.15±0.80 SD	
Ontario, Canada/eutrophic pond	Adult male (summer)	5.52±2.23 SD	Galbraith et al., 1988
	Adult female (summer)	5.03±1.12 SD	
	Juvenile (both) (summer)	1.40±0.20 SD	
Michigan	Adult male	4.16±0.28 SE	
	Adult female	3.16±0.20 SE	

[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a)

TABLE 3-101
Body Weights (kg) of the Snapping Turtle (*Chelydra serpentina*)

Location	Sex	Mean	Reference
	Juvenile (both)	0.80±0.07 SE	
NS	at hatching	0.0057	Ernst and Barbour, 1972
NS	at hatching	0.0089	Ewert, 1979
Massachusetts	mm carapace:		Graham and Perkins, 1976
	118	0.33	
	127	0.44	
	134	0.53	
	167	1.03	
	192	1.51	
	220	2,362	

Food Habits and Diet Composition

Snapping turtles are omnivorous. In early spring, when limited aquatic vegetation exists in lakes and ponds, they may eat primarily animal matter; however, when aquatic vegetation becomes abundant, they become more herbivorous (Pell, 1941, cited in Graves and Anderson, 1987). Young snapping turtles are primarily carnivorous and prefer smaller streams where aquatic vegetation is less abundant (Lagler, 1943; Pell, 1941, cited in Graves and Anderson, 1987). Snapping turtles consume a wide variety of animal material including insects, crustaceans, clams, snails, earthworms, leeches, tubificid worms, freshwater sponges, fish (adults, fry, and eggs), frogs and toads, salamanders, snakes, small turtles, birds, small mammals, and carrion and plant material including various algae (Alexander, 1943; Graves and Anderson, 1987; Hammer, 1969; Punzo, 1975). Budhabatti and Moll (1988) observed no difference between the diets of males and females who fed at the surface, midpelagic, and benthic levels. Bramble (1973) suggested that the pharyngeal mechanism of feeding (i. e., drawing water with food objects into the mouth) prevents snapping turtles from ingesting food above the air-water interface. Diet composition of the snapping turtle has been described in the literature (Table 3-102).

Food Consumption Rate

Kiviat (1980) reported a summer food ingestion rate of 0.01 to 0.016 g/g-day for captive snapping turtles in New York.

Water Consumption Rate

No data on water consumption was available in the literature.

TABLE 3-102
Diet Composition of the Snapping Turtle (*Chelydra serpentina*)

Location/Habitat	Dietary Composition	Spring	Summer	Fall	Winter	Reference
Tennessee/embayment	Adults:					Meyers-Schoene and Walton, 1990
	Fish		83.7			
	Vegetation		13.6			(percent wet volume; gastrointestinal
	Clams		0.2			tract contents)
	Mud and Rocks		2.5			
Connecticut/lakes, ponds, streams, swamps	adults and Juveniles:					Alexander, 1943
	(plants)		(36.5)			
	algae		12.8			(percent wet volume; stomach contents)
	(animals)		(54.1)			
	crayfish		8.9			
	fiddler crab		2.7			
	sucker		3.2			
	bullhead		6.3			
	sunfish		7.5			
	unknown fish		12.4			
	(misc.)		(9.4)			

Soil Ingestion

Soil ingestion rates of 4.5 percent and 5.9 percent of the diet were estimated for the box turtle and the eastern painted turtle, respectively, by Beyer et al. (1994). Meyers-Schoene and Walton (1990) recorded mud and rocks in the stomach contents of snapping turtles that accounted for 2.5 percent of the diet.

Respiration Rate

No data concerning the respiration rate in snapping turtles was available in the literature.

Metabolism

The estimated basal metabolic rate for an adult female is 3.2 kcal/kg BW/day and 3.0 for an adult male, using an equation presented in Robinson et al. (1983) and using body weights from Congdon et al. (1986) (30 percent of the body weight was subtracted to account for the weight of the shell). Lynn and von Brand (1945) presented a resting metabolic rate of 2.54 L O_2/kg BW/day for a 7.18 kg turtle.

Habitat Requirements

In the east, snapping turtles are found in and near permanent ponds, lakes, and marshes. However, in the arid west, the species is primarily found in larger rivers, because these are the only permanent water bodies (Toner, 1960, cited in Graves and Anderson, 1987). They are most often found in turbid waters with a slow current (Graves and Anderson, 1987). They spend most of their time lying on the bottom of deep pools or buried in the mud in shallow water with only their eyes and nostrils exposed. Froese (1978) observed that young snapping turtles show a preference for areas with some obstructions that may provide cover or food.

Home Range

Most turtles stay primarily within the same marsh or in one general area from year to year (Hammer, 1969; Obbard and Brooks, 1981). The summer home range includes a turtle's aquatic foraging areas, but females may need to travel some distance outside of the foraging home range to find a suitable nest site (DeGraaf and Rudis, 1983). Obbard and Brooks (1980) found that females tagged at their nesting site moved an average of 5.5 km (± 1.8 SD) from the nest site afterwards. Lonke and Obbard (1977) observed that 91.9 percent of the turtles in one population returned to the same nesting site a year after having been tagged there. Home ranges overlap both between and within sexes (Obbard and Brooks, 1981). Young snapping turtles use different habitats than adults; they tend to remain in small streams until shortly before maturity, when they migrate to habitats preferred by adults (e. g., ponds, marshes, lakes) (Hammer, 1971; Minton, 1972, cited in Graves and Anderson, 1987). Galbraith et al. (1987) presented a summer home range for males in Lakes in Ontario, Canada of 0.7 ha. Obbard and Brooks (1981) also estimated summer home ranges for the turtle in lakes in Ontario. Mean home ranges were 3.79 ha for females, 3.21 ha for males, and 3.44 ha for both. In fresh tidal wetlands in New York home ranges were presented as 8.9 ha for males and 7.2 ha for nonbreeding females (Kiviat, 1980).

Population Density

The density of snapping turtles appears to be positively correlated with the productivity of the surface water body (e. g., density in a eutrophic surface water body is higher than in an oligotrophic lake) (Galbraith et al., 1988). Specific habitat characteristics and intraspecific interactions contribute to the variability of observed population densities in snapping turtles (Froese and Burghardt, 1975). Estimates of population density during the summer in Ontario, Canada, were 1.5 turtles/ha for adult males in oligotrophic lakes (Galbraith et al., 1987), 2.3 turtles/ha for juvenile and adult males and females in oligotrophic waters, 60.4 turtles/ha for adult and juvenile males and females in eutrophic ponds, and 29.3 turtles/ha for adult and juvenile males and females in eutrophic ponds in other studies (Galbraith et al., 1988). In Tennessee ponds, Froese and Burghardt (1975) estimated a population density of 59 turtles/ha for both male and female adults.

Population Dynamics/Survival

Females do not begin laying eggs until age 6 to 19 years depending on latitude and when they reach an appropriate size (approximately 200 mm carapace) (Galbraith et al., 1989; Mosimann and Bider, 1960). Males mature a few years earlier than females. Females may lay one or two clutches per season (Minton, 1972, cited in Graves and Anderson, 1987).

Hammer (1969) found that mammalian predators destroyed over 50 percent of the turtle nests in a South Dakota marsh, and in undisturbed nests, hatchling success was less than 20 percent. Petokas and Alexander (1980) observed a 94 percent predation rate of nests under study in northern New York. Adult mortality is low, corresponding with the long lives exhibited by these turtles. Annual Mortality reported by Glabraith and Brooks (1987) ranged from 3 to 7 percent. Longevity was observed to be at least 24 years in a Michigan marsh and at least 19 years in a South Carolina river (Gibbons, 1987).

Reproduction/Breeding

Mating occurs any time turtles are active from spring through fall, depending on latitude (Ernst and Barbour, 1972). Some investigators believe that male snapping turtles are territorial (Kiviat, 1980; Pell, 1941, cited in Galbraith et al., 1987), but Galbraith et al. (1987) doubts that males defend their home ranges against other males. Sperm may remain viable in the female for several years (Smith, 1956). Nesting occurs from late spring to early fall, peaking in June (Ernst and Barbour, 1972). Hammer (1969) observed that larger, older females nested earlier in the season than did smaller, younger ones. Females often move up small streams to lay eggs (Ewert, 1976, cited in Graves and Anderson, 1987). The nest site may be in the soil of banks or in muskrat houses but more commonly is in the open on south-facing slopes and may be several hundred meters from water (DeGraaf and Rudis, 1983). The turtle digs a 4-to 7-in cavity on dry land, preferably in sand, loam, or vegetable debris.

Minton (1972) observed that 1 to 2 clutches are laid per year in Indiana and Ernst and Barbour (1972) routinely found that more than one clutch was laid per year. Mean clutch size can vary from 16.6 to 49 (range, 12-87 eggs) (Hammer, 1969; Congdon et al., 1987; Iverson, 1977). Moreover, clutch size has been found to increase with female body size. Congdon et al. (1987) calculated the relationship between clutch size (CS) and plastron length (PL in mm) for a population in southeastern Michigan:

$$CS = -21.227 + 0.242\ (PL),\ (r = 0.409,\ n = 65).$$

Clutch size has also been positively correlated with latitude (Petokas and Alexander, 1980). Incubation has been estimated at 105 days in Ontario, Canada (Obbard and Brooks, 1981) and had an estimated range of 67-73 days in Wisconsin (Ewert, 1979). The duration of incubation is inversely related to soil temperature (Ernst and Barbour, 1972; Yntema, 1978, cited in Graves and Anderson, 1987). In more northerly populations, hatchlings may overwinter in the nest (DeGraaf and Rudis, 1983).

Behavior and Social Organization

Snappers are most active at night. During the day, they occasionally leave the water to bask on shore, but basking is probably restricted by intolerance to high temperatures and by rapid loss of moisture (Ernst and Barbour, 1972). In a study in Ontario, Canada, Obbard and Brooks (1981) found that the turtles were active in the early morning and early evening and basked in the afternoon but were rarely active at night. Active turtles were found in deeper waters than inactive snappers (Obbard and Brooks, 1981). Cloacal temperatures of 18.7 to 32.6 °C were reported for snapping turtles captured in the water in Sarasota County, Florida, between May and October (Punzo, 1975).

Snapping turtles usually enter hibernation by late October and emerge sometime between March and May, depending on latitude and temperature. To hibernate, they burrow into the debris or mud bottom of ponds or lakes, settle beneath logs, or retreat into muskrat burrows or lodges. Snapping turtles have been seen moving on or below the ice in midwinter. Large congregations sometimes hibernate together (Budhabatti and Moll, 1988; Ernst and Barbour, 1972).

3.4.2 Painted Turtle (*Chrysemys picta*)[1]

Painted turtles are in the order Testudines, Family Emydidae. Pond and marsh turtles (i.e., sliders, cooters, red-bellied turtles, and painted turtles) are small to medium-sized semi-aquatic turtles well known for basking in the sun. Painted turtles are the most widespread of these in North America, ranging across the continent.

Distribution

The painted turtle is largely aquatic, living in shallow-water habitats, and is among the most conspicuous of the basking turtles. There are four subspecies in the United States (only one reaching slightly into Canada), distinguished by color variations, body size, and range: *C. p. picta* (eastern painted turtle; 11.5 to 15.2 cm; range Nova Scotia to Alabama), *C. p. marginata* (midland painted turtle; 11. 5 to 14 cm; range southern Quebec and southern Ontario to Tennessee), *C. p. dorsalis* (southern painted turtle; 10 to 12. 5 cm; range southern Illinois to the Gulf), and *C. p. bellii* (western painted turtle; the largest of the subspecies, 9 to 18 cm; range southwest Ontario and Missouri to the Pacific Northwest) (Conant and Collins, 1991). *C. p. dorsalis* is the smallest subspecies and also one of the smallest emydid turtles in North America (Moll, 1973). Hybridization occurs between subspecies in areas where their ranges overlap (e. g., *bellii* × *marginata* hybrids may occur in areas of Michigan) (Snow, 1980).

Body Size and Weight

Painted turtles are medium-sized turtles (10 to 18 cm). Males are smaller than females; adult males average from 170 to 190 g, whereas adult females average from 260 to 330 g in some populations (Congdon et al., 1986; Ernst, 1971b). In general, the shell comprises approximately 30 percent of the total wet weight of turtles of this size (Hall, 1924). Frazer et al. (1991) estimated a relationship between plastron length (PL in mm) and age (t in years) for a population in Michigan in the 1980's using von Bertalanffy growth equations:

$$PL = 111.8\,(1 - 0.792e^{-0.184t}) \text{ for males, and}$$

$$PL = 152.2\,(1 - 0.852e^{-0.128t}) \text{ for females.}$$

Congdon et al. (1982) reported a relationship between plastron length (PL in mm) and body weight (Wt in grams) for painted turtles:

$$\log e(Wt) = -6978 + 2.645 \log e(PL).$$

Eggs weigh 4 to 6 g, and neonates retain a large yolk mass that they draw on for the first few months of life (Cagle, 1954).

TABLE 3-103
Body Weights (g) of the Painted Turtle (*Chrysemys picta*)

[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a)

Location	Sex/age	Mean	Range	Reference
Pennsylvania (*picata* x *marginata*)	female/ adult	266.5 ± 60.1 SD	83.5 - 450.3	Ernst, 1971 b
	male/adult	189.1 ± 52.3 SD	102.0 - 274.5	
Michigan	female/ adult	326.7 ± 4.95 SE		Congdon et al., 1986
	male/adult	176.9 ± 1.92 SE		
	both/juvenile	64.2 ± 1.59 SE		
c Virginia (*picta*)	NS/at hatching	3.7 ± 0.2 SD		Mitchell, 1985
Iowa	NS/at hatching	4.1 ± 0.61 SD		Ratterman and Ackerman, 1989

Food Habits and Diet Composition

Painted turtles are omnivorous. Depending on habitat and on age, painted turtles may consume predominantly vegetation or predominantly animal matter. Marchand (1942, cited in Mahmoud and Klicka, 1979) found in one population that juveniles consumed approximately 85 percent animal matter and 15 percent plant matter, whereas the adults were primarily herbivorous, consuming 88 percent plant matter and 12 percent insects and amphipods. Knight and Gibbons (1968) found oligochaets, cladocera, dragonfly nymphs, lepidopteran larvae, and tendipedid larvae and pupae to dominate the animal component of the diet and filamentous algae to dominate the plant component of the diet in a population living in a polluted river in Michigan. Adult painted turtles in a Pennsylvania population were found to consume only 40 percent plant matter (Ernst and Barbour, 1972), whereas in a Michigan marsh and elsewhere, painted turtles of all ages apparently consumed 95 to 100 percent plant matter (Cahn, 1937, cited in Smith, 1961; Gibbons, 1967). Some carrion also may be consumed (Mount, 1975).

TABLE 3-104
Diet Composition of the Painted Turtle (*Chrysemys picta*)

Location/Habitat	Dietary Composition	Spring	Summer	Reference
Michigan/Marsh	Plants		> 95	Gibbons, 1967
				(percent wet weight; stomach contents)
Michigan/polluted river	Plants	31.6	38.7	Knight and Gibbons, 1968
	Animals:	77.3	72.3	
	Oligochaeta	--	30.0	(percent wet weight; stomach contents)
	Cladocera	1.5	48.5	
	Odonata nymphs	60.0	38.3	
	Lepidoptera larvae	1.0	50.0	
	Tendipedidae larva	30.8	7.7	
	Tendipedidae pupae	36.7	10.0	

TABLE 3-104
Diet Composition of the Painted Turtle (*Chrysemys picta*)

Location/Habitat	Dietary Composition	Spring	Summer	Reference
	Detritus	7.8	1.9	
Pennsylvania (*picta*)/NS	Snails		12.1	Ernst and Barbour, 1972
	Amphipods		3.0	
	Crayfish		7.5	(percent wet volume; stomach contents)
	Insects		11.5	
	Fish		13.0	season not specified
	Other animals		14.1	
	Algae		14.7	
	Vascular plants		24.1	
	Other plants		0.8	

Food Consumption Rate

No literature data was available concerning the food consumption rate of painted turtles.

Water Consumption Rate

Trobec and Stanley (1971) reported *C.p. bellii* held in tap water to consume water at a rate up to 0.025 g/g-day in a Wisconsin lab. Other studies have found the average water ingestion rate for adults of both sexes to be 0.02 g/g-day with a range of 0.016-0.022 g/g-day (measured as evaporative loss) (Ernst, 1972).

Soil Ingestion

A soil ingestion rate of 5.9 percent of the diet was reported for eastern painted turtle by Beyer et al. (1994).

Respiration Rate

A resting inhalation rate of 0.0025 m^3 air/kg BW/day was reported for adult turtles in the lab (Milsom and Chan, 1986).

Metabolism

Congdon et al. (1982) estimated the metabolic rate for *C.p. marginata* females, based on an annual energy budget and assuming that females lay one clutch of eggs per year after their seventh year. The mean metabolic rate (kcal/day averaged over one year) for juvenile females of one year was 0.06, for juvenile females of 3 years was 0.30, for juvenile females of 5 years was 0.53, for juvenile females of 7 years was 0.77, for adult females of 9 years was 1.12, for adult females of 11 years was 1.23, and for adult females of 13 years was 1.28. Stockard and Gatten (1983) estimated metabolic rate for adults at 25 °C on land to be

0.73 L O_2/kg BW/day and in water to be 0.22 lO_2/kg BW/day in North Carolina. Juveniles had estimates of 0.39 at 25 °C and 5.06 while feeding. During a one day fast, rates dropped to 3.44 L O_2/kg BW/day with a drop to 1.98 during a 10 day fast and 1.57 on a 19 day fast (Sievert et al., 1988; Stockard and Gatten, 1983).

Habitat Requirements

Painted turtle habitat requirements include soft and muddy bottoms, basking sites, and aquatic vegetation (Sexton, 1959). Painted turtles prefer slow-moving shallow water such as ponds, marshes, ditches, prairie sloughs, spring runs, canals, and occasionally brackish tidal marshes (Conant and Collins, 1991). They frequent areas with floating surface vegetation for feeding and for cover (Sexton, 1959). These areas tend to be warmer than more open water, which is important in the early fall as temperatures begin to drop (Sexton, 1959). For winter hibernation or dormancy, painted turtles seek deeper water (Sexton, 1959). If outlying marsh areas are dry during the summer, the turtles may return to the more permanent bodies of water sooner (McAuliffe, 1978). Painted turtles sometimes inhabit stagnant and polluted water (Smith, 1956).

Home Range

In spring, as the winter ice melts, many painted turtles move away from the ponds in which they hibernated to more shallow ponds and marshes with surface vegetation (Sexton, 1959). Movements averaging 63 to 144 meters characterized one population in Michigan (Sexton, 1959). The summer home range includes the painted turtle's foraging areas and basking sites. Females find nesting sites on dry land outside of the foraging range; Congdon and Gatten (1989) found nests to average 60 meters from the edge of a foraging marsh. Sexton (1959) reported average movements of 86 to 91 m in summer and 88 to 130 m in fall. Females initiate nesting migrations during daylight hours, and most finish their nests before dark on the same day (Congdon and Gatten, 1989). In winter, painted turtles generally move back to the deeper ponds for hibernation (DeGraaf and Rudis, 1983).

Population Density

Reported breeding densities range from 11.1 turtles/ha in Saskatchewan (MacCulloch and Secoy, 1983) to 828 turtles/ha in Michigan marshes (Frazer et al., 1991). Ponds and marshes of Pennsylvania had breeding densities of 240 to 941 turtles/ha (mean, 590; Ernst, 1971c). Accurate censuses are difficult, however (Bayless, 1975), and the distribution of painted turtles in summer is highly clumped, corresponding to the patches of floating aquatic vegetation (Sexton, 1959).

Population Dynamics/Survival

Sexual maturity is attained in about 2 to 8 years, depending on the sex and size of the turtle and growing season (Christiansen and Moll, 1973; Ernst and Barbour, 1972). Males reach sexual maturity 1 to a few years earlier than females (Moll, 1973). Once sexual maturity is reached, growth of painted turtles slows or essentially ceases (Ernst and Barbour, 1972). Older, larger females tend to produce larger clutch sizes and larger eggs than younger, smaller females (Mitchell, 1985). In more southerly populations, painted turtles produce more clutches annually with fewer eggs each than in more northerly populations (Moll, 1973; Snow, 1980; Schwarzkopf and Brooks, 1986). Predation causes most nest losses, usually within the first 2 days after laying (Tinkle et al., 1981). Annual mortality rates of 0 to 14 percent for females in Saskatchewan and of 2 to 46 percent for males in New York were reported by Zwiefel (1989). Mitchell (1988) observed a range of 4 to 6 percent for both males and females in Virginia and a rate of 54 percent for both male and female juveniles. Male and female painted turtles have been observed to live up to 31 and 34 years, respectively (Frazer et al., 1991).

Reproduction/Breeding

Mating usually occurs in spring and summer but may continue into the fall (Ernst, 1971c; Gibbons, 1968a; Gist et al., 1990). Nesting occurs somewhat later (Cagle, 1954; Ernst and Barbour, 1972; Moll, 1973). In fact, Gist et al. (1990) indicated that October was the peak mating season in Ohio. Eggs are often laid in high banks (DeGraaf and Rudis, 1983). Clutches per year range from 1 to more than 3 (Schwarzkopf and Brooks, 1986; Snow, 1980; Moll, 1973). Average clutch size as presented by MacCulloch and Secoy (1983) was 19.8 (range, 17-23 eggs) in Saskatchewan. In Wisconsin, Moll (1973) reported a mean clutch size of 10.7 (range, 4-16 eggs) compared to just 4.8 eggs/clutch (range, 2-9 eggs) in Tennessee. In Michigan, mean clutch size was found to be 7.6 (range, 2-11; Congdon and Tinkle, 1982). The duration of the incubation period depends on soil temperature, and hatchlings may overwinter in the nest in more northerly populations (Gibbons and Nelson, 1978). In Pennsylvania, southeast Wisconsin, and northwest Minnesota, incubation lasted 65-80, 60-65, and 72-99 days, respectively (Ernst, 1971c; Ewert, 1979).

Behavior and Social Organization

Painted turtles are diurnal and usually spend their nights sleeping submerged (Ernst, 1971c). During the day, they forage in the late morning and late afternoon and bask during the rest of the day (Ernst, 1971c). Active feeding does not occur until water temperatures approach 20 ° C, and these turtles are most active around 20.7 to 22.4 °C (Ernst, 1972; Ernst and Barbour, 1972; Hutchinson, 1979). Basking is most frequent in the spring, summer, and fall, but occasionally painted turtles bask during warm spells in the winter (Ernst and Barbour, 1972). The species does not appear to be territorial and can be found in large aggregations, particularly at favorite basking sites (Ernst, 1971c).

Sexton (1959) divided the annual activity cycle of painted turtles into five parts: (1) the prevernal, which begins with the final melting of winter ice and lasts until late March, or when the turtles begin to move in mass out of the hibernation ponds; (2) the vernal, from late March to late May, when the submerged aquatic plants important to the turtles grow to the surface of the water (the initiation of feeding and mating activities and the emergence of the hatchling turtles from the nests of the previous year also occur during this season); (3) the aestival, extending from June through August, when the turtles forage, grow, nest, and return to their winter hibernation ponds; (4) the autumnal, including September through November or when a permanent ice cover forms; and (5) the winter season, which lasts while the water is permanently covered with ice.

Most painted turtles become dormant during the colder months usually beginning in late October (Congdon et al., 1982; Smith, 1956) but will become active during warm periods in the winter (Ernst and Barbour, 1972). *C. picta* usually hibernates in muddy bottoms of ponds (DeGraaf and Rudis, 1983). Taylor and Nol (1989) found painted turtles overwintering in an

Ontario pond in areas with a mean water depth of 0.32 m (range 0.2 to 0.48 m), mean sediment depth of 0.79 m (0.5 to 0.95 m), and mean sediment temperature of 4.1 °C (3 to 6 °C). During hibernation, painted turtles shift toward more anaerobic metabolism, supported by glycolysis of liver and skeletal muscle glycogen (Seymour, 1982). After emerging from hibernation, the turtles convert the accumulated lactate to glucose in the liver (using aerobic metabolism) (Seymour, 1982).

3.4.3 Eastern Box Turtle (*Terrapene carolina*)[1]

The eastern box turtle is in the order Testudines, Family Emydidae. Box turtles are the most terrestrial of the Emydid turtles, having close-fitting shells that have allowed them to adapt well to terrestrial life. They are found throughout the eastern and central United States and into the southwest. They are omnivorous.

Distribution

The eastern box turtle (*Terrapene carolina carolina*) ranges from northeastern Massachusetts to Georgia, west to Michigan, Illinois, and Tennessee (Conant and Collins, 1991). There are four subspecies of *T. carolina*, all found within the eastern United States: *T. c. carolina* (above), *T. c. major* (Gulf Coast box turtle; the largest subspecies, restricted to the Gulf Coast), *T. c. triunguis* (three-toed box turtle; Missouri to south-central Alabama and Texas), and *T. c. bauri* (Florida box turtle; restricted to the Florida peninsula and keys) (Conant and Collins, 1991).

Body Size and Weight

The eastern box turtle is small, with adults ranging from 11.5 to 15.2 cm in length (plastron) and approximately 300 to over 400 g. Hatchlings weigh approximately 8 to 10 g. Turtles continue to grow throughout their lives; however, their growth rate slows after reaching sexual maturity (Ernst and Barbour, 1972), and growth rings are no longer discernable after 18 to 20 years (Stickel, 1978). Body fat reserves in a Georgia population averaged 0.058 to 0.060 g of fat per gram of lean dry weight from spring through fall (Brisbin, 1972).

TABLE 3-105
Body Weights (g) of the Eastern Box Turtle (*Terrapene carolina*)

Location	Sex/age/season	Mean	Reference
Georgia (*carolina*)/captive	Female/adult/fall	381 ± 29 SE	Brisbin, 1972
	Male/adult/fall	398 ± 47 SE	
Georgia (*carolina*)/NS	Female/adult/spring	388 ± 29 SE	Brisbin, 1972
	Male/adult/spring	369 ± 47 SE	
South Carolina	Female/adult/NS	372	Congdon and Gibbons, 1985
Florida (*major*)	NS/at hatching	8.8	Ewert, 1979
Indiana (*carolina*)	NS/at hatching	8.4	Ewert, 1980
Tennessee	NS/2 months	21	Allard, 1948

[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a)

TABLE 3-105
Body Weights (g) of the Eastern Box Turtle (*Terrapene carolina*)

Location	Sex/age/season	Mean	Reference
	NS/1.3 years	40	
	NS/3.3 years	54	

Food Habits and Diet Composition

Adult *T. carolina* are omnivorous (Ernst and Barbour, 1972). When young, they are primarily carnivorous, but they become more herbivorous as they age and as growth slows (Ernst and Barbour, 1972). They consume a wide variety of animal material, including earthworms, slugs, snails, insects and their larvae (particularly grasshoppers, moths, and beetles), crayfish, frogs, toads, snakes, and carrion; they also consume vegetable matter, including leaves, grass, berries, fruits, and fungi (DeGraaf and Rudis, 1983). A high proportion of snails and slugs may comprise the animal matter in the diet (Barbour, 1950), and seeds can become an important component of the plant materials in the late summer and fall (Klimstra and Newsome, 1960).

TABLE 3-106
Diet Composition of the eastern box turtle (*Terrapene carolina*)

Location/Habitat	Dietary Composition	Spring	Summer	Fall	Reference
Kentucky (*carolina*)/Cumberland Mountains	Snails		60		Barbour, 1950
	Crayfish		15		
	Plants		12.5		(percent volume; stomach contents)
	Crickets		7.5		
	Unidentified seeds		5		
Illinois (*carolina*)/forest, prairie	Plant matter	35	39	20	Klimstra and Newsome, 1960
	Insects (adults)	18	12	12	
	Insects (larvae)	4	5	9	(percent wet volume; digestive tract)
	Seeds	8	16	33	
	Gastropoda	18	6	8	
	Isopoda	<1	5	3	
	Diplopoda	3	2	5	
	Decapoda	2	2	0	
	Annelida	1	1	4	
	Mammals	2	<1	2	
	Reptiles	1	3	1	
	Birds	3	1	<1	

Food Consumption Rate

No data on food consumption rates for box turtles was available in the literature.

Water Consumption Rate

No data on water consumption rate in box turtles was available in the literature. However, water consumption rates of 0.025 g/g-day and 0.02 g/g-day have been recorded for eastern painted turtles (Trobec and Stanley, 1971; Ernst, 1972). Because painted and box turtles are of a similar size, it is likely that water consumption will be similar

Soil Ingestion

Beyer et al. (1994) reported a soil ingestion rate for box turtles in Maryland of 4.5 percent of the diet.

Respiration Rate

No data on the respiration rate for box turtles was available in the literature. A resting inhalation rate of 0.0025 m^3 air/kg BW/day was reported for adult eastern painted turtles (Milsom and Chan, 1986). Because box turtles are of a similar body mass, inhalation rates are likely to be comparable.

Metabolism

The estimated basal metabolic rate for an average adult female is 5.4 kcal/kg BW/day, using an equation from Robinson et al. (1983) and body weights from Brisbin (1972). Note: 30 percent of the reported body weight was subtracted to eliminate the weight of the shell; (Hall, 1924). This metabolic rate is estimated assuming a temperature of 20 °C.

Habitat Requirements

Typical box turtle habitats include open woodlands, thickets, and well-drained but moist forested areas (Stickel, 1950), but occasionally pastures and marshy meadows are utilized (Ernst and Barbour, 1972). In areas with mixed woodlands and grasslands, box turtles use grassland areas in times of moderate temperatures and peak moisture conditions; otherwise, they tend to use the more moist forested habitats (Reagan, 1974). Many turtles are killed attempting to cross roads, and fragmentation of habitat by roads can severely reduce populations (DeGraaf and Rudis, 1983; Stickel, 1978).

Home Range

Measures of the foraging home range for box turtles range from 0.5 ha to just over 5 ha (Dolbeer, 1969; Schwartz et al., 1984). Dolbeer (1969) reported a summer home range of 0.46 ha for box turtles in woodlands of Tennessee. Larger home ranges were observed in bottomland forests of Maryland (male, 1.2 ha and female, 1.1 ha; Stickel, 1989) and in mixed woods and fields of Missouri (male, 5.2 ha and female, 5.1 ha; Schwartz et al., 1984). A female may need to search for suitable nest site (e. g., slightly elevated sandy soils) (Ernst and Barbour, 1972) outside of her foraging home range (Stickel, 1950). Winter hibernacula tend to be within the foraging home range (Stickel, 1989).

Population Density

Population density varies with habitat quality, but studies linking density to particular habitat characteristics are lacking. In some areas, population densities have declined steadily over the past several decades (Schwartz and Schwartz, 1974; Stickel, 1978). Some investigators attribute the decline to increasing habitat fragmentation and obstacles (e. g., highways) that prevent females from reaching or returning from appropriate nesting areas (Stickel, 1978; DeGraaf and Rudis, 1983). Population density in Tennessee woodlands ranged from 2.8 to 3.6 turtles/ha (Dolbeer, 1969) and in Maryland forests from 17 to 35 turtles/ha (Schwartz et al., 1984).

Population Dynamics/Survival

Sexual maturity is attained at about 4 or 5 years (Ernst and Barbour, 1972) to 5 to 10 years of age (Minton, 1972, cited in DeGraaf and Rudis, 1983). One to four clutches may be laid per year, depending on latitude (Oliver, 1955, cited in Moll, 1979; Smith, 1961). Clutch size ranges from three to eight eggs, averaging three to four in some areas (Congdon and Gibbons, 1985; Ernst and Barbour, 1972; Smith, 1956). Juveniles generally comprise a small proportion of box turtle populations, for example, 18 to 25 percent in one population in Missouri (Schwartz and Schwartz, 1974) and 10 percent in a study in Maryland (Stickel, 1950). Some individual box turtles may live over 100 years (Graham and Hutchinson, 1969, cited in DeGraaf and Rudis, 1983; Oliver, 1955, cited in Auffenberg and Iverson, 1979). Oliver (1955) reported one box turtle living up to 138 years in captivity. Nichols (1939a) reported a mean lifespan of 20 years that ranged up to 80 years.

Reproduction/Breeding

Box turtles are solitary except briefly during the mating season. Individuals restrict their activities to a foraging home range, but home ranges of different individuals can overlap substantially (Stickel, 1950). Mating usually occurs in the spring but may continue into fall, and eggs are laid in late spring and summer (Ernst and Barbour, 1972). The female digs a 3-to 4-inch cavity in sandy or loamy soil in which she deposits her eggs and then covers the nest with soil. Nests tend to be constructed several hundred meters from the female's foraging home range in the warmer and drier uplands (Stickel, 1989). Box turtles in Illinois had just one clutch per year (Smith, 1961), while those in Florida had up to 4 clutches per year. Clutch size ranges from 2-7 eggs with means of 3.4 and 4 reported in South Carolina and Washington, DC, respectively (Congdon and Gibbons, 1985; Smith, 1956). The duration of incubation depends on soil temperatures, and sometimes hatchlings overwinter in the nest. Incubation in the northwest was reported to last 78-102 days (Ewert, 1979), compared to a mean of 99 days (range, 69-161) in Minnesota and Washington, DC (Ewing, 1933). The young are semi-aquatic but seldom seen (Smith, 1956).

Behavior and Social Organization

The species is diurnal and spends the night resting in a scooped depression or form that the turtle digs in the soil with its front feet (Ernst and Barbour, 1972; Stickel, 1950). *T. carolina* are most active in temperate, humid weather (Stickel, 1950). In the summer, they avoid high temperatures during midday by resting under logs or leaf litter, in mammal burrows, or by congregating in mudholes (Smith, 1961; Stickel, 1950). In the hottest weather, they may enter shaded shallow pools for hours or days (Ernst and Barbour, 1972). In the cooler temperatures, they may restrict their foraging activities to midday (Stickel, 1950). In the laboratory, locomotion is maximal between 24 and 32 °C (Adams et al., 1989). In the field, their mean active body temperature is approximately 26 °C (Brattstrom, 1965, cited in Hutchinson, 1979).

In the northern parts of its range (northeastern Massachusetts, Michigan, Illinois), the eastern box turtle enters hibernation in late October or November and emerges in April. In Louisiana, Penn and Pottharst (1940, cited in Ernst and Barbour, 1972) found that *T. c. major* hibernated when temperatures fell below 65 °F. To hibernate, the box turtle burrows into loose soil and debris or mud of ponds or stream bottoms. Congdon et al. (1989) found a South Carolina population of box turtles to occupy relatively shallow burrows (less than 4 cm) compared with those occupied by box turtles in colder regions (up to 46 cm). Dolbeer (1971) found hibernacula of box turtles in Tennessee to be under 15.5 cm of leaf litter and 5.8 cm of soil on average. In southern states, during rainy and warm periods, box turtles may become active again (Dolbeer, 1971). In Florida, the box turtle may be active all year (Ernst and Barbour, 1972).

3.4.4 Racer Snake (*Coluber constrictor*)[1]

The racer snake is in the order Squamata. All racer snakes and whipsnakes (*Masticophis* spp.) belong to the family Colubridae, along with 84 percent of the snake species in North America. Colubrids vary widely in form and size and can be found in numerous terrestrial and aquatic habitats. The more terrestrial members of this family also include some brown and garter snakes; lined snakes; earth snakes; hognose snakes; small woodland snakes; green snakes; speckled racer and indigo snakes; rat snakes; glossy snakes; pine, bull, and gopher snakes; kingsnakes and milk snakes; scarlet, long-nosed, and short-tailed snakes; ground snakes; rear-fanged snakes; and crowned and black-headed snakes (Conant and Collins, 1991).

Distribution

Racer snakes are slender and fast moving and are found in a wide variety of terrestrial habitats. They are one of the most common large snakes in North America (Smith, 1961). There are 11 subspecies in North America, limited to the United States and Mexico: *C. c. constrictor* (northern black racer; southern Maine to northeastern Alabama), *C. c. flaviventris* (eastern yellowbelly racer; Montana, western North Dakota, and Iowa south to Texas), *C. c. foxii* (blue racer; northwest Ohio to eastern Iowa and southeast Minnesota), *C. c. anthicus* (buttermilk racer; south Arkansas, Louisiana, and east Texas), *C. c. etheridgei* (tan racer; west-central Louisiana and adjacent Texas), *C. c. helvigularis* (brownchin racer; lower Chipola and Apalachicola River Valleys in Florida panhandle and adjacent Georgia), *C. c. latrunculus* (blackmask racer; southeast Louisiana along east side of Mississippi River to northern Mississippi), *C. c. mormon* (western yellow-bellied racer; south British Colombia to Baja California, east to southwest Montana, western Wyoming, and western Colorado), C. c. oaxaca (Mexican racer; south Texas and Mexico), *C. c. paludicola* (Everglades racer; southern Florida Everglades region and Cape Canaveral area), and *C. c. priapus* (southern black racer; southeastern states and north and west in Mississippi Valley).

Body Size and Weight

Adult racer snakes are usually 76 to 152 cm in total length (Conant and Collins, 1991). Brown and Parker (1984) developed an empirical relationship between snout-to-vent length

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[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a)

(SVL) and body weight for male and female racers of the *mormon* subspecies in northern Utah:

weight (g) = -100.80 + 2.93 SVL (cm) females (nonreproductive), and

weight (g) = -82.65 + 2.57 SVL (cm) males.

The equations apply only over a limited range of body sizes (40 to 70 cm) where the relationship is approximately linear instead of exponential, and measures of SVL exclude the tail. Fitch et al. (1963) estimated that the tail measures 28 percent of the SVL of young females and 31 percent of the SVL of young males.

Kaufman and Gibbons (1975) determined a relationship between length and weight for both sexes of a South Carolina population:

weight (g) = 0. 0003 SVL (cm) 2.97 (± 0.15 2SE)

for both sexes, with 95 percent confidence interval for constant (intercept in log-transform regression) = 0.00015 to 0.00058.

Racers from populations in the northeastern United States tend to be the largest, while those from the far west and south Texas are the smallest (Fitch, 1963). Just prior to egg-laying, the eggs can account for over 40 percent of a gravid female's body weight (Brown and Parker, 1984). At hatching, racers weigh about 8 or 9 g. Weight gain during the first year is rapid, with both sexes increasing their weight after hatching by approximately 3.2 times in the first year (Brown and Parker, 1984). One-year-old females nearly double their weight during their second year (Brown and Parker, 1984). By the time females are 3 years old (when most reach sexual maturity), they are 1.3 times heavier than the males (Brown and Parker, 1984).

TABLE 3-107
Body Weights (g) of the Racer Snake (*Coluber constrictor*)

Location			Mean	Range	Reference
Utah (*mormon*)	Males:				Brown and Parker, 1984
	Yrs	mm SVL			
	<1	266	8.3		
	1	420	27.0		
	2	486	41.0		
	3	520	49.1		
	4	541	53.4		
	5	564	60.4		
	6	573	61.2		
Utah (*mormon*)	Females:				Brown and Parker, 1984
	Yrs	mm SVL			
	<1	272	8.8		
	1	430	28.4		

TABLE 3-107
Body Weights (g) of the Racer Snake (*Coluber constrictor*)

Location			Mean	Range	Reference
	2	524	51.6		
	3	575	66.2		
	4	599	71.4		
	5	620	79.4		
	6	632	84.0		
Kansas (*flaviventris*)	Males:				Fitch, 1963
	Yrs	mm SVL			
	2	615	68.2		
	3	706	102.1		
	4	757	139		
	5	806	152.4		
	6	827	175.9		
	7	845	181.2		
	8	868	217.5		
Kansas (*flaviventris*)	Females:				Fitch, 1963
	Yrs	mm SVL			
	2	644	83.5		
	3	810	149.4		
	4	866	212.3		
	5	914	209.6		
	6	965	245.9		
	7	974	251.3		
	Neonate 215 mm SVL		4.16	2.4 - 5.8	Fitch, 1963

Food Habits and Diet Composition

Racers are foraging generalists that actively seek their prey. Their varied diet includes small mammals (e. g., mice, voles), insects, amphibians (especially frogs), small birds, birds' eggs, snakes, and lizards (Brown and Parker, 1982; Fitch, 1963; Klimstra, 1959). In early spring, *C. c. flaviventris* feeds primarily on mammals and from May to October feeds primarily on insects (Klimstra, 1959). They often capture new prey before fully digesting previously captured prey (Fitch, 1982). Females, which are larger than males, tend to consume a higher proportion of vertebrate prey than do the males (Fitch, 1982). Males tend to spend more time climbing among foliage in low shrubs and trees and consuming insects (Fitch, 1982).

TABLE 3-108
Diet Composition of the Racer Snake (*Coluber constrictor)*

Location/Habitat	Dietary Composition	Spring	Summer	Fall	Reference
s Illinois/pastures, meadows	Insects	20	40.0	64	Klimstra, 1959
	Small mammals	62	27	21	
	Amphibians	5	13	3	(percent volume; digestive tracts)
	Reptiles	7	8	--	
	Birds	4	6	8	
	Other	2	6	4	
Kansas (*flaviventris)* throughout state	Small mammals		65.7		Fitch, 1963
	Orthopterans		14.3		
	Lizards		9.2		(percent wet weight; scats and stomach contents)
	Snakes		4.2		
	Misc. insects		1.9		
	Birds		3.5		
	Frogs		1.2		
Kansas (*flaviventris)* woodland, grassland	Mice		15.4		Fitch, 1963
	Orthopterans		4.6		
	Lizards		61.5		(percent wet weight; stomach contents)
	Frogs		12.6		
	Snakes		5.1		
	Crickets		0.8		

Food Consumption Rate

Fitch et al. (1982) estimated that the subspecies *flaviventris* in Kansas ate approximately four times its body weight over the 213-day active season from spring to fall, a mean ingestion rate of 0.02 g/g-day.

Water Consumption Rate

No data concerning water consumption rates in racer snakes were available in the literature.

Soil Ingestion

No data concerning soil ingestion in racer snakes were available in the literature.

Respiration Rate

No data concerning respiration rates in racer snakes were available in the literature.

Metabolism

No data concerning metabolism in racer snakes were available in the literature. However, the basal metabolic rate for male snakes of 6.78 kcal/kg BW/day and 6.19 kcal/kg BW/day for females can be calculated using an equation from Robinson et al., 1983 and body weights of 3 year old snakes from Fitch et al. (1963). A temperature of 20 °C was assumed.

Habitat Requirements

Racers can be found in moist or dry areas, abandoned fields, open woodlands, mountain meadows, rocky wooded hillsides, grassy-bordered streams, pine flatwoods, roadsides, and marshes from sea level to 2,150 m in elevation (Behler and King, 1979). Racers are partially arboreal (Behler and King, 1979; DeGraaf and Rudis, 1983). *C. c. constrictor* seems to prefer forest edges and open grassy, shrubby areas (Fitch, 1963, 1982). In autumn, most racers move into woodlands to find rock crevices in which to overwinter (Fitch, 1982).

Home Range

C. c. constrictor appears to have a definite home range (Smith, 1956) and requires large tracts of mixed old fields and woodlands (M. Klemens, pers. comm., cited in DeGraaf and Rudis, 1983). Fitch (1963) described four types of movement depending on the season and activity: (1) those in areas where hibernation occurs (e. g., rocky ledges), (2) seasonal migration between hibernation and summer ranges during spring and fall, (3) daily activities within a home range during the active season, and (4) wandering movements during which the racer shifts its activities. Home ranges for males (3 ha) and females (1.8 ha) during the summer in Kansas woodlands were reported by Fitch (1963).

Population Density

Population densities of between 0.3 and 7 active snakes/ha have been recorded in different habitats and areas (Fitch, 1963; Turner, 1977). Data on population densities are limited due to the difficulty in accurately censusing snakes.

Population Dynamics/Survival

Male racers can reach sexual maturity by 13 to 14 months, whereas females tend not to mature until 2 or 3 years of age (Behler and King, 1979; Brown and Parker, 1984). Juvenile snakes suffer higher mortality rates (e.g., 80 percent) than adult snakes (e.g., 20 percent) (Brown and Parker, 1984). Fitch (1963) reported mortality rates of 58 percent for 2-year-old male and female snakes, 25 to 30 percent for 3- to 6-year-old male and female snakes, and 38 percent for 7-year-old male and female snakes. Longevity has been observed up to 20 years in cold desert shrub areas of Utah (Brown and Parker, 1982).

Reproduction/Breeding

The species breeds in the spring or early summer. Eggs are laid in the summer in rotting wood, stumps, decaying vegetable matter, or loose soil and hatch about 2 months later (Behler and King, 1979; DeGraaf and Rudis, 1983). Racers defend home territories (DeGraaf and Rudis, 1983; Smith, 1956) but more than one male may mate with one female in a breeding season. Adult females produce at most a single clutch each year (some may reproduce only in alternate years) (Fitch, 1963). In general, the number of eggs in a clutch is proportional to the size of the female and ranges from 4 to 31 eggs (Fitch, 1963). Mean clutch size in snakes from desert shrub regions of Utah was only 5.28 eggs (range, 4-8; Brown and Parker, 1984), compared to 16.8 eggs (range, 7-31) and 12.6 (range, 7-21) in two other subspecies (Fitch, 1963). Incubation lasts approximately 40 days to 2 months, depending on temperature (Behler and King, 1979; Smith, 1956). Eggs may double in size before hatching by absorbing water from the surrounding soil (Fitch, 1963). Hatching peaks in mid-late August and ends sometime in September (Fitch, 1963; Brown and Parker, 1982).

Behavior and Social Organization

Racers are diurnal and spend a good portion of the daylight hours foraging (Vermersch and Kuntz, 1986). The species is fast moving and may be encountered in almost any terrestrial situation (Fitch, 1982). Hammerson (1987) observed California racers to bask in the sun after emerging from their night burrows or crevices until their internal body temperature reached almost 34 °C, after which they would begin actively foraging. When temperatures are moderate, racers will spend much of their time during the day in the open above ground; at high temperatures, racers may retreat underground (Brown and Parker, 1982). Although racers are good climbers, they spend most of their time on the ground (Behler and King, 1979). When searching for food or being pursued, the racer snake will not hesitate to climb or swim (Smith, 1961).

In fall, racers move to their hibernacula fairly directly and begin hibernation soon thereafter (Brown and Parker, 1982; Fitch, 1963). Racers hibernate in congregations of tens to hundreds of snakes (Brown and Parker, 1984), sometimes with copperheads and rattlesnakes, often using deep rock crevices or abandoned woodchuck holes (Parker and Brown, 1973). They are among the earliest snakes to emerge from hibernation (DeGraaf and Rudis, 1983).

3.4.5 Northern Water Snake (*Nerodia sipedon sipedon*)[1]

The northern water snake is in the order Squamata. Water snakes and salt marsh snakes (genus *Nerodia*) belong to the family Colubridae, along with 84 percent of the snake species in North America. Colubrids vary widely in form and size and can be found in numerous habitats, including terrestrial, arboreal, aquatic, and burrowing. The more aquatic types of snakes in this family include water snakes, salt marsh snakes, swamp snakes, brown snakes, and garter and ribbon snakes (Conant and Collins, 1991).

Distribution

The northern water snake is largely aquatic and riparian. It ranges from Maine and southern Quebec to North Carolina. It also inhabits the uplands of western North Carolina and

[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a)

adjacent portions of Tennessee and Virginia, and its range extends west to eastern Colorado (Conant and Collins, 1991). Three additional subspecies are recognized, distinguished by range and habitat: *N. s. pleuralis* (midland water snake; ranges from Indiana to Oklahoma and the Gulf of Mexico and south of the mountains to the Carolinas, preferring fast-moving streams), *N. s. insularum* (Lake Erie water snake; inhabits islands of Put-in-Bay, Lake Erie), and *N. s. williamengelsi* (Carolina salt marsh water snake; inhabits the Outer Bank islands and mainland coast of Pamlico and Core sounds, North Carolina) (Behler and King, 1979; Conant and Collins, 1991).

Body Size and Weight

The northern water snake is typically 61 to 107 cm in total length (Conant and Collins, 1991). Island populations of the species tend to be larger than mainland ones (King, 1986). King (1986) estimated the relationship between snout-to-vent length (SVL) and body weight for Lake Erie water snakes (*N. s. insularum*):

weight (g) = 0. 0005 SVL (cm)3.07 all snakes;

weight (g) = 0. 0009 SVL (cm)2.88 females; and

weight (g) = 0. 0008 SVL (cm)2.98 males.

Measures of SLV exclude the tail. Kaufman and Gibbons (1975) estimated that the tail represents 21.8 percent (± 0.010 SE) of the total length of a female and 25.7 percent of the total length of a male.

Kaufman and Gibbons (1975) determined a relationship between length and weight for both sexes of a South Carolina population:

weight (g) = 0. 0004 SVL (cm) 3.15 (± 0.12 SE) all snakes

(95 percent CI for intercept = 0.00015 to 0.0011). Immediately after emergence from hibernation, females begin to gain weight and continue gaining weight until giving birth in late summer. Weight loss associated with parturition in one population ranged from 28.2 to 45.5 percent of the female's weight just prior to parturition (King, 1986).

Food Habits and Diet Composition

Northern water snakes consume primarily fish and amphibians and, to a lesser extent, insects and small mammals (Raney and Roecker, 1947; Smith, 1961). Diet varies according to the age (and size) of the snake and food availability (DeGraaf and Rudis, 1983). Young snakes forage in shallow riffles and cobble bars, primarily waiting for prey to move within range (letter from K. B. Jones, U. S. Environmental Protection Agency Environmental Monitoring Systems Laboratory, to Susan B. Norton, January 6, 1992). Tadpoles comprise a large proportion of the diet of young snakes in some areas (Raney m and Roecker, 1947). Adults are strong swimmers and can swim and dive for fish, often capturing large specimens (e.g., 20 to 23 cm brown trout; 19 cm bullhead; 20+ cm lamprey) (Lagler and Salyer, 1945). They also tend to consume bottom-dwelling fish species (e. g., suckers) (Raney and Roecker, 1947). In New York, Brown (1958) found that *N. s. sipedon* consumed the most food between June and August; they consumed little during the remaining months prior to hibernation.

TABLE 3-109
Body Weights (g) of the Water Snake (*Nerodia sipedon*)

Location	Sex/age/season	N	Mean	Range	Reference
Kansas	Both /adults		207	up to 480	Fitch, 1982
New York (*sipedon)*	Both/juveniles (1 yr)		7.0 ± 2.3 SD	5.3 - 10.4	Brown, 1958
	Both/juveniles (2 yr)	2	29.0	25.2 - 32.7	
	Male /juvenile (3 yr)	1	53.2		
	Both/adults (5-6 yr)		210.0 ± 65 SD	114 - 255	
Ohio, Ontario (*insularum*)	Both/neonate		4.8	3.6 - 6.6	King, 1986

TABLE 3-110
Diet Composition of the Water Snake (*Nerodia sipedon)*

Location/Habitat	Dietary Composition	Spring	Summer	Fall	Reference
Georgia/aquatic	Esocidae		7.0		Camp et al., 1980
	Catostomidae		22.5		
	Percidae		15.7		(percent wet volume, stomach contents)
	Proteidae		51.9		
	Cyprinidae		1.5		
	Centrarchidae		0.3		season not specified
	Crawfish		1.5		
n lower Michigan/ streams	Trout		64		Alaxender, 1977
	Non-trout fish		7		
	Unidentified fish		1		(percent wet weight; stomach contents)
	Crustacea		1		
	Amphibia		14		
	Birds and mammals		12		
	Unidentified		1		
n lower Michigan/lakes	Minnows			9.1	Brown, 1958
	Darters			1.4	
	Amphibia			52.8	(percent volume; stomach contents)
	Sculpin (Cottidae)			2.2	

TABLE 3-110
Diet Composition of the Water Snake (*Nerodia sipedon)*

Location/Habitat	Dietary Composition	Spring	Summer	Fall	Reference
	Trout perch (Percopsis)			2.8	
	Game fishes (Perca)			14.1	
	Burbot (Lota)			17.4	
	Catfish (Ictaluridae)			0.3	

Food Consumption Rate

Brown (1958) found that adult (5-6 years) *N. s. sipedon* held in captivity and fed a diet of fish at 23 °C had an average food consumption rate of 0.061 g/g-d, while one year old juvenile had a rate a 0.088 g/g-day and 2-3 year old juveniles had a rate of 0.043 g/g-d.

Water Consumption Rate

No data concerning water consumption rates for water snakes were available from the literature.

Soil Ingestion

No data concerning soil ingestion rates for water snakes were available from the literature.

Respiration Rate

No data concerning respiration rates for water snakes were available from the literature.

Metabolism

No data concerning metabolism in the northern water snake were available in the literature. However, the resting metabolic (L O_2/kg-d) rates for *Nerodia rhombifera*, a similar species, were reported by Gratz and Hutchinson (1977):

15 °C 0.607 ± 0.035 SE with a range of 0.39 - 0.94

25 °C 3.290 ± 0.100 SE with a range of 2.81 - 4.44

35 °C 7.330 ± 0.230 SE with a range of 5.70 - 9.99

It is likely that these values may be representative of those for water snakes.

Habitat Requirements

The northern water snake prefers streams but can be found in lakes and ponds and nearby riparian areas (King, 1986; Smith, 1961). In the Carolinas and Virginia, they can be found from mountain lakes and streams to large coastal estuaries (Martof et al., 1980). They are absent from water bodies with soft muddy bottoms, which may interfere with foraging (Lagler and Salyer, 1945). In Lake Erie, *N. s. insularum* occurs in shoreline habitats where rocks or vegetation provide refugia (King, 1986).

Home Range

The northern water snake usually stays in the same area of a stream, in the same pond, or in an adjacent pond for several years (Fraker, 1970). Snakes along streams have larger home ranges than snakes in ponds and lakes (Fraker, 1970). Fraker (1970) found that for large ponds (e. g., 1, 500 to 2,000 m^2), the home range of an individual snake is essentially the entire pond. In fish hatcheries with smaller ponds, individual snakes frequent more than one pond (Fraker, 1970).

Population Density

Population density estimates for water snakes usually are expressed relative to a length of shoreline. Values from 34 to 381 snakes/km of shoreline have been reported for streams and Lake Erie islands (King, 1986; Beatson, 1976). Mean population densities on Lake Erie islands was 138 snakes/km of shoreline (range, 22-381: King, 1986), and average densities in Kansas streams was 34-41 snakes/km of shoreline (Beatson, 1976).

Population Dynamics/Survival

Northern water snakes reach sexual maturity at 2 or 3 years of age, with males generally maturing earlier and at a smaller size than females (Feaver, 1977, cited in King, 1986; King, 1986). Clutch sizes vary from 5 or 10 to 50 or 60 depending on location and on female size. The proportion of females breeding in a given year increases with increasing female size, as does clutch size and offspring weight (King, 1986). King determined the relationship of litter size to female SVL for Lake Erie water snakes (*N. s. insularum*):

$$\text{litter size} = -12.45 + 0.41 \text{ SVL (cm)}.$$

Feaver (1977, cited in King, 1986) determined the relationship for a Michigan population:

$$\text{litter size} = -23.55 + 0.55 \text{ SVL (cm)}.$$

Females produce only one clutch per year (Beatson, 1976). Information on annual survivorship of juveniles or adults was not identified in the literature reviewed.

Reproduction/Breeding

The northern water snake breeds primarily in early spring, and the young are born from late summer to fall (i. e., viviparous) (DeGraaf and Rudis, 1983). Only one litter/year is produced (Bauman and Metter, 1977; Beatson, 1976). Reported mean litter sizes were 11.8 (range, 4-24), 20.8 (range, 6-34), 22.9 (range, 9-50), and 33 (range, 13-52) in various habitats of Michigan, Ohio in 1958, Ohio in 1986, and Illinois, respectively (Feaver, 1977; Camin and Ehrlich, 1958; King, 1986; Smith, 1961). The rate of development before hatching is temperature dependent (Bauman and Metter, 1977). A gestation of 58 days has been reported (Bauman and Metter, 1977). Parturition generally begins in mid to late August and ends in September (Smith, 1961; King, 1986; Martof et al., 1980).

Behavior and Social Organization

The northern water snake is active both day and night but is most active between 21 and 27 °C (Brown, 1958; Smith, 1961). During the day, they are found in areas that provide basking sites and are not found in heavily shaded areas (DeGraaf and Rudis, 1983; Lagler and Salyer, 1945). They may become inactive and seek shelter, however, if temperatures exceed 27 °C (Brown, 1958; Lagler and Salyer, 1945). They become torpid at temperatures less than 10 ° C (Brown, 1958). In autumn, the northern water snake leaves aquatic habitats to overwinter in rock crevices or in banks nearby (DeGraaf and Rudis, 1983; Fitch, 1982). King (1986) reported hibernation in Ontario and Ohio to begin in mid-October and end in mid-April. In Michigan, Feaver (1977) reported hibernation to begin in November and end in late March.

3.4.6 Eastern Newt (Notophthalmus viridescens)[1]

The eastern newt is in the order Caudata, Family Salamandridae. *Notophthalmus*, the genus comprising the eastern newts, inhabits eastern North America. A different genus, *Taricha*, comprises the western newts along the Pacific coast of North America. Unlike other salamanders, the skin of newts is rough textured, not slimy. Eastern newts are primarily aquatic; western newts are terrestrial. The life cycle of eastern newts is complex. Females deposit their eggs into shallow surface waters. After hatching, the larvae remain aquatic for 2 to several months before transforming into brightly colored terrestrial forms, called efts (Healy, 1974). Postlarval migration of efts from ponds to land may take place from July through November, but timing varies between populations (Hurlbert, 1970). Efts live on land (forest floor) for 3 to 7 years (Healy, 1974). They then return to the water and assume adult characteristics. In changing from an eft to an adult, the newt develops fins and the skin changes to permit aquatic respiration (Smith, 1961). Occasionally newts omit the terrestrial eft stage, especially in the species located in the southeast coastal plain (Conant and Collins, 1991) and along the Massachusetts coast (Healy, 1974). These aquatic juveniles have the same adaptations (i. e., smooth skin and flattened tail) as the aquatic adults, but are not sexually mature (Healy, 1973). Under favorable conditions, adults are permanently aquatic; however, adults may migrate to land after breeding due to dry ponds, high water temperatures, and low oxygen tension (Hurlbert, 1969). The life cycle of western newts does not include the eft stage (Conant and Collins, 1991). The eastern newt has both aquatic and terrestrial forms. The aquatic adult is usually yellowish-brown or olive-green to dark brown above, yellow below. The land-dwelling eft is orange-red to reddish-brown, and its skin contains tetrodotoxin, a neurotoxin and powerful emetic.

Distribution

There are four subspecies of eastern newts: *N. v. viridescens* (red-spotted newt; ranges from Nova Scotia west to Great Lakes and south to the Gulf states), *N. v. dorsalis* (broken-striped newt; ranges along the coastal plain of the Carolinas), *N. v. louisianensis* (central newt; ranges from western Michigan to the Gulf), and *N. v. piaropicola* (peninsula newt; restricted to peninsular Florida) (Conant and Collins, 1991). Neoteny occurs commonly in the peninsula and broken-striped newts. In the central newt, neoteny is frequent in the southeastern coastal plain. In the red-spotted newt, neoteny is rare (Conant and Collins, 1991). Neotenic newts are mature and capable of reproduction but retain the larval from, appearance and habits (Conant and Collins, 1981).

[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

Body Size and Weight

Adult eastern newts usually are 6.5 to 10.0 cm in total length (Conant and Collins, 1991). In North Carolina, *N. v. dorsalis* efts ranged from 2.1 to 3.8 cm snout-to-vent length (SVL), which excludes the tail, and adults ranged from 2.0 to 4.4 cm SVL (Harris, 1989; Harris et al., 1988). Healy (1973) found aquatic juveniles 1 year of age to range from 2.0 to 3.2 cm SVL. Adult eastern newts weigh approximately 2 to 3 g (Gill, 1979; Gillis and Breuer, 1984), whereas the efts generally weigh 1 to 1.5 g (Burton, 1977; Gillis and Breuer, 1984).

TABLE 3-111
Body Weights (g) of the Eastern Newt (*Notophthalmus viridescens*)

Location	Sex/age/season	Mean	Range	Reference
New York	Both/adults	2.24 ± 0.71 SD	1.12-3.52	Gillis and Breuer, 1984
Virginia	Female/prebreeding	3.05 ± 0.06 SE		Gill, 1979
	Female/postbreeding	2.49 ± 0.06 SE		
	Male/prebreeding	2.49 ± 0.03 SE		
	Male/postbreeding	2.76 ± 0.03 SE		
Massachusetts	Adults:			Pitkin, 1983
	Both/spring	1.71 ± 0.43 SD		
	Both/summer	2.13 ± 0.44 SD		
	Both/winter	1.94 ± 0.33 SD		
	Both/fall	1.63 ± 0.28 SD		
South Carolina	Larvae:			
	12.8 mm SVL	0.04 ± 0.025 SD		Taylor et al., 1983
	21.9 mm SVL			
New York	Eft:			Gillis and Breuer, 1984
	Both		0.42 - 1.82	
New Hampshire (*viridescens)*	Both	1.10 ± 0.40 SD		Burton, 1977
New York	Both/summer	1.45	0.63 - 2.17	Stefanski et al., 1989

Food Habits and Diet Composition

Adult eastern newts are opportunistic predators that prey underwater on worms, insects and their larvae (e. g., mayfly, caddisfly, midge, and mosquito larvae), small crustaceans and molluscs, spiders, amphibian eggs, and occasionally small fish. Newts capture prey at the surface of the water and on the bottom of the pond, as well as in the water column (Ries and Bellis, 1966). The shed skin (exuvia) is eaten and may comprise greater than 5 percent of the total weight of food items of both the adult and eft diets (MacNamara, 1977). Snails are an important food source for the terrestrial eft (Burton, 1976). Efts feed only during rainy summer periods (Behler and King, 1979; Healy, 1973). Healy (1975) noted that in late August and September, efts often were found clustered around decaying mushrooms feeding on adult and larval dipterans. In a northern hardwood hemlock forest in New York, MacNamara (1977) found that most prey of adult migrants and immature efts were from the upper litter layer, soil surface, or low vegetation.

TABLE 3-112
Diet Composition of the Eastern Newt (*Notophthalmus viridescens*)

Location/Habitat	Dietary Composition	Summer	Fall	Reference
New Hampshire (Viridescens)/small oligotrophic lake	Aquatic adults:			Burton, 1977
	Ephemeroptera	7.5	7.5	
	Odonata	31.9	1.9	
	Lepidoptera	13.7	0.9	
	Diptera	5.8	0.3	
	Other insects	9.9	0.6	(percent wet weight; stomach and gut contents)
	Cladocerans	5.1	84.1	
	Amphipoda	5.6	3.1	
	Pelycepoda	6.2	1.5	
	N. viridescens larvae	11.4	0.0	
	Other	3.2	0.1	
New York/leaf litter surface in forest	Efts:			MacNamara, 1977
	Basommatophora		5.5	
	Stylommatophora		18.3	
	Acari		13.8	
	Collembola		10.4	(percent dry weight stomach contents)
	Thysanoptera		3.4	
	Homoptera		4.7	
	Coleoptera (adult)		2.3	
	Coleoptera (larvae)		3.5	
	Lepidoptera larvae		7.9	
	Diptera (adult)		9.7	
	Diptera (larvae)		10.6	
	Hymenoptera		5.8	
New Hampshire (Viridescens)/small oligotrophic lake	larvae:			Burton, 1977
	Zygoptera (Odonata)		0.8	
	Chironomidae (diptera)		16.2	
	Cladocera		12.7	
	Ostracoda		5.3	
	Hyallela azteca (Amphipoda)		55.1	

TABLE 3-112
Diet Composition of the Eastern Newt (*Notophthalmus viridescens*)

Location/Habitat	Dietary Composition	Summer	Fall	Reference
	Sphaerium spp. (Pelycepoda)		9.4	
	Planorbidae (Gastropoda)		0.5	
	Rhizopoda (Protozoa)		0.01	

Food Consumption Rate

No data concerning food consumption rates in eastern newts were available in the literature.

Water Consumption Rate

No data concerning water consumption rates in eastern newts were available in the literature.

Soil Ingestion

No data concerning soil ingestion in the eastern newt were available in the literature.

Respiration Rate

No data concerning inhalation rats in eastern newts were available in the literature.

Metabolism

The estimated adult post-breeding basal metabolic rates are 16.2 and 16.7 kcal/kg BW/day for males and females, respectively, using an equation from Robinson et al. (1983) and post breeding body weights from Gill (1979). Metabolic rates assume a temperature of 20 °C. Using the same equation and temperature, as well as body weights from Taylor et al. (1988), the estimated mean basal metabolic rate for larvae (12.8 mm) is 43.5 kcal/kg BW/day. This compares to a basal metabolic rate of 20.1 kcal/kg BW/day for efts (71.0 mm) based on body weights from Gillis and Breuer (1984). The values for the larvae should be used with caution; however, because these animals are smaller than any used to developed the allometric equations. Stefanski et al. (1989) estimated a resting metabolic rate of 1.47 L O_2/kg BW/day and an active metabolic rate of 4.27 L O_2/kg BW/day for efts at 15 °C.

Habitat Requirements

Larval and adult eastern newts are found in ponds, especially those with abundant submerged vegetation, and in weedy areas of lakes, marshes, ditches, backwaters, and pools of shallow slow-moving streams or other unpolluted shallow or semi-permanent water. Terrestrial efts inhabit mixed and deciduous forests (Bishop, 1941, cited in Sousa, 1985) and are found in moist areas, typically under damp leaves, brush piles, logs, and stumps, usually in wooded habitats (DeGraaf and Rudis, 1983). Adequate surface litter is important, especially during dry periods, because efts seldom burrow (Healy, 1981, cited in Sousa, 1985).

Home Range

For adult newts, Bellis (1968) found the mean distance between capture and recapture sites to be about 7 m, indicating small home ranges. Harris (1981, cited in DeGraaf and Rudis, 1983) did not find any defined home range or any territoriality for males. Most efts around a pond in Pennsylvania remained within 1.5 m of the shore (Bellis, 1968). Healy (1975) estimated the home range for terrestrial efts in a Massachusetts woodland to be 270 m^2 (0.03 ha) and located approximately 800 m from the ponds where the adults and larvae were located. For efts in oak/pine forests of Massachussetts Healy (1975) estimated a home range of 0.0087 ha (range, 0.0028-0.0153 ha).

Population Density

Populations of aquatic adults may reach high local densities, whereas terrestrial efts exhibit lower population densities. Recorded population densities for terrestrial efts range from 34 efts/ha (ranging from 20 to 50 eft/ha) in a North Carolina mixed deciduous forest (Shure et al., 1989) to 300 efts/ha in a Massachusetts woodland (Healy, 1975). Harris et al. (1988) observed a density of 1.4 adult newts/m^2 (14,000 adult newts/ha) in a shallow pond in North Carolina in the winter, whereas the summer population density was only 0.2 adults/m^2 (2, 000 adults/ha). The spring density for larvae in the same location was 65,000 larvae/ha, while summer and fall densities were 25,000 and 10,000 larvae/ha, respectively. In South Carolina ponds and wetlands, Taylor et al. (1988) found a larvae spring density of 21,000 larvae/ha. In contrast, Burton (1977) reported lake densities in New Hampshire of just 130 to 173 adults/ha for the entire lake and 50 to 2,600 adults/ha for the fringes of the lake.

Population Dynamics/Survival

Many populations of the eastern newt reach sexual maturity when the eft stage returns to the water and changes to the adult form (Healy, 1974). However, under certain conditions such as low larval density, most of the larvae present have been shown to metamorphose directly into adults or even into sexually mature larvae (Harris, 1987). In experimental ponds, densities of 22 larvae/m^2 resulted in metamorphosis to eft by the majority, while a density of 5.5 larvae/m^2 resulted in metamorphosis directly to the adult form or sexual maturation without metamorphosis (Harris, 1987). Adult density also influences reproduction. Morin et al. (1983) found that doubling adult density resulted in a reduction of offspring produced to one-quarter that produced by adults at the lower density (i.e., from 36 offspring/female in tanks containing 1.1 females/m^2 to 9.7 offspring /female in tanks containing 2.2 females/m^2). The adult life expectancy noted by Gill (1978b) was 2.1 breeding seasons for males and 1.7 breeding seasons for females. Amphibian blood leeches (ectoparasites) are likely to be a primary source of mortality for adults; they also prey directly on larvae (Gill, 1978a). Annual mortality as reported by Gill (1978a) was 54.1 to 59.5 percent for females and 45.8 to 53.1 for males in mountain ponds of Virginia.

Reproduction/Breeding

In south-central New York, breeding takes place in late winter or early spring, usually in lakes, ponds, and swamps (Hurlbert, 1970). Similar timing was observed in newts breeding in South Carolina (Gibbons and Semlitsch, 1991), but newts in North Carolina did not begin breeding until April (Harris et al., 1988). Ovulation and egg deposition occur over an extended period (McLaughlin and Humphries, 1978). Mean clutch sizes are 200 to 400 eggs (Behler and King, 1979). Females overwintering on land can store sperm for at least 10 months (Massey, 1990). Spawning underwater, the female deposits eggs singly on leaves of submerged plants, hiding and wrapping each in vegetation (Gibbons and Semlitsch, 1991; Smith 1956). The time to hatching depends on temperature (DeGraaf and Rudis, 1983). Smith (1961) found typical incubation periods to be 14 to 21 days in Illinois, whereas the incubation period observed by Behler and King (1979) was 21 to 56 days.

In late summer or early fall, the larvae transform into either aquatic juveniles or terrestrial efts (Behler and King, 1979). Harris (1987) showed that low larval density stimulated neoteny in larvae under experimental conditions. Larval growth rates were higher in ponds with low larval densities (Harris, 1987; Morin et al., 1983). Growth rates for aquatic juveniles are highest in the spring; however, maximum seasonal growth for the terrestrial efts occurs between June and September when the temperature is optimal for active foraging (Healy, 1973). Larvae were found to metamorphosis into the eft stage at 2 to 3 months of age in Illinois (Smith, 1961) and 6 months of age in Massachusetts (Healy, 1974). It then takes the eft approximately 1-3 years before it metamorphosis into the adult newt (Gibbons and Semlitsch, 1991). Adults reach sexual maturity between 4 to 8 years of age if the eft stage is included in the life-cycle, whereas sexual maturity is reached at just 2 years of age when metamorphosis directly to the adult stage occurs (Healy, 1974).

Behavior and Social Organization

Adult newts are often seen foraging in shallow water, and efts are often found in large numbers on the forest floor after it rains (Behler and King, 1979). Efts may be found on the open forest floor even during daylight hours (Conant and Collins, 1991), but they rarely emerge if the air temperature is below 10 °C (Healy, 1975).

Most adults remain active all winter underwater on pond bottoms or in streams (DeGraaf and Rudis, 1983). Some adults overwinter on land (Hurlbert, 1970) and migrate to ponds during the spring to breed (Hurlbert, 1969). If the water body freezes to the bottom, adults may be forced to hibernate on land or to migrate to another pool (Smith, 1956). Efts hibernate on land, burrowing under logs and debris. Hurlbert (1969) observed that efts migrated to ponds for the first time in the spring and fall. In Virginia fall migration of adults to hibernaculae reportedly begins in August or September and ends in November (Gill, 1978a), while spring migration of adults to breeding ponds begins in late March and ends in late April (Massey, 1990).

3.4.7 Green Frog (*Rana clamitans*)[1]

The green frog is in the order Anura, Family Ranidae. These are typical frogs with adults being truly amphibious, living at the edge of water bodies and entering the water to catch

[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a).

prey, to flee danger, and to spawn (Behler and King, 1979). This profile covers medium-sized ranids.

Distribution

The green frog is usually found near shallow fresh water throughout much of eastern North America. Two subspecies are recognized: *R. c. clamitans* (the bronze frog; ranges from the Carolinas to northern Florida, west to eastern Texas, and north along the Mississippi Valley to the mouth of the Ohio River) and *R .c. melanota* (the green frog; ranges from southeastern Canada to North Carolina, west to Minnesota and Oklahoma but rare in much of Illinois and Indiana, introduced into British Columbia, Washington, and Utah) (Conant and Collins, 1991).

Body Size and Weight

The green frog is a medium-sized ranid usually between 5.7 and 8.9 cm snout-to-vent length (SVL) (Conant and Collins, 1991; Martof et al., 1980). Its growing period is primarily confined to the period between mid-May and mid-September (Martof, 1956b). Females are usually larger than males (Smith, 1961). Adults typically weigh between 30 and 70 g (Wells, 1978). Hutchinson et al. (1968) developed an allometric equation relating green frog surface area (SA in cm) to body weight (Wt in grams):

$$SA = 0.997\ Wt^{0.712}.$$

TABLE 3-113
Body Weights (g) of the Green Frog (*Rana clamitans*)

Location	Sex/age	Mean	Range	Reference
New Brunswick, Canada	Both/juveniles and adults	49.1 ± 20.0 SD	25.5-103.5	McAlpine and Dilworth, 1989
New York (*melanota*)	Male/adult	44.0 ± 10.0 SD	27.0 - 66.0	Wells, 1968
New York	NS/at metamorphosis	3		Pough and Kamel, 1984

Food Habits and Diet Composition

Adult green frogs are terrestrial feeders among shoreline vegetation. They consume insects, worms, small fish, crayfish, other crustaceans, newts, spiders, small frogs, and molluscs. Stewart and Sandison (1973) found that terrestrial beetles often are their most important food item but noted that any locally abundant insect along the shoreline may be consumed in large numbers. There is a pronounced reduction in food consumption during the breeding period for both males and females (Mele, 1980). During the breeding season, males spend most of their energy defending breeding territories, and females expend their energy producing eggs (Wells, 1977). Fat reserves acquired during the pre-breeding period compensate for reduced food intake during the breeding period (Mele, 1980). Jenssen and Klimstra (1966) found that green frogs consume most of their food in the spring and eat little during the winter. Food eaten in the spring, summer, and fall consists mostly of terrestrial prey, whereas winter food is composed mostly of aquatic prey (Jenssen and Klimstra, 1966). Juveniles (sexually immature frogs) eat about half the volume of food consumed by adults over the course of a year (Jenssen and Klimstra, 1966). Tadpoles are herbivorous (DeGraaf and Rudis, 1983). Green frogs eat their cast skins following molting; the casting of skin is frequent during midsummer (Hamilton, 1948).

TABLE 3-114
Diet Composition of the Green Frog (*Rana clamitans*)

Location/ Habitat	Dietary Composition	Spring	Summer	Fall	Winter	Reference
s Illinois/stream	Adults:					Jenssen and Klimstra, 1966
	Mineral	--	--	--	2.6	
	Plant	5.7	8.3	4.2	0.5	(percent wet volume; stomach contents)
	Plulmonata	15.7	18.3	6.4	11.0	
	Oligochaeta	2.1	0.8	2.3	6.4	
	Amphipoda	1.2	0.1	--	4.6	
	Isopoda	5.6	1.4	--	4.6	
	Decapoda	--	--	4.1	--	
	Julioforma	7.5	0.3	1.7	--	
	Araneida	2.8	3.4	6.6	7.4	
	Odonata	1.6	12.4	5.9	--	
	Orthoptera	0.9	3.0	1.5	--	
	Hemiptera	1.0	7.0	6.1	2.2	
	Coleoptera	9.6	19.6	15.9	9.1	
	Lepidoptera	25.4	7.0	25.1	--	
	Diptera	6.0	5.2	4.5	10.3	
	Hymenoptera	9.9	6.0	13.5	--	
	Salientia	--	--	3.9	--	

Food Consumption Rate

No data concerning the food consumption rate of green frogs were available in the literature.

Water Consumption Rate

No data concerning water consumption rates of green frogs were available in the literature.

Soil Ingestion

No data concerning soil ingestion rates in green frogs were available in the literature.

Respiration Rate

No data concerning inhalation rates in green frogs were available in the literature.

Metabolism

The estimated basal metabolic rate for an adult green frog is 8.08 kcal/kg BW/day using an equation from Robinson et al. (1983) and body weights from McAlpine and Dilworth (1989), assuming a temperature of 20 °C. Estimated metabolic rate at metamorphosis is 15.8 kcal/kg BW/day using equation the same equation and temperature, as well as body weights from Pough and Kamel (1984).

Habitat Requirements

Adult green frogs live at the margins of permanent or semi-permanent shallow water, springs, swamps, streams, ponds, and lakes (Wells, 1977). Martof (1953b) found green frogs primarily to inhabit the banks of streams. They also can be found among rotting debris of fallen trees (Behler and King, 1979; Conant and Collins, 1991). Juveniles prefer shallower aquatic habitats with denser vegetation than those preferred by adults (Martof, 1953b). McAlpine and Dilworth (1989) observed that green frogs inhabited aquatic habitats about two-thirds of the time and terrestrial habitats the remaining time. Similarly, Martof (1953b) found that the green frog relies on terrestrial habitats for feeding and aquatic habitats for refuge from desiccation, temperature extremes, and enemies. Ponds used by green frogs are usually more permanent than those used by other anuran species (Pough and Kamel, 1984).

Home Range

The green frog home range includes its foraging and refuge areas in and around aquatic environments. During the breeding period, the male's home range also includes its breeding territory (Wells, 1976). Martof (1953b) found that roughly 80 percent of adult frogs captured in the spring and again in the fall occupied the same home ranges. The mean home range for non-breeding adults in shallow waters of south Michigan as reported by Martof (1953b) was 0.0065 $\pm$ 0.0036 SD ha (range, 0.0020-0.02 ha). Wells, (1977) reported a mean length of shoreline occupied by breeding males in ponds in New York of 4 to 6 meters while shoreline used in densely vegetated near-shore areas of ponds was 1 to 1.5 meters.

Population Density

During the breeding season, green frog densities at breeding ponds can exceed several hundred individuals per hectare (Wells, 1978). Adult male frogs space their breeding territories about 2 to 3 m apart (Martof, 1953a). Wells (1978) reported a green from population density of 476 adult males/ha and 567 adult females/ha in an artificial pond.

Population Dynamics/Survival

Sexual maturity is attained in 1 or 2 years after metamorphosis; individuals may reach maturity at the end of the first year but do not attempt to breed until the next year (Martof, 1956a, b). Most females lay one clutch per year, although some may lay two clutches, about 3 to 4 weeks apart (Wells, 1976). In natural populations, green frogs can live to approximately 5 years of age (Martof, 1956b). No data on survival rates were presented in the literature reviewed.

Reproduction/Breeding

Green frogs breed from spring through the summer, spawning at night (Smith, 1961; Wells, 1976). Female green frogs stay in non-breeding habitat until it is time to spawn (Martof, 1956a). In preparation for breeding, males establish territories near shore that serve as areas for sexual display and as defended oviposition sites (Wells, 1977). Males establish calling sites within their territories where they attempt to attract females (Wells, 1977). Females visit male territories to mate and lay their egg masses. The masses are contained in films of jelly and are deposited in emergent, floating, or submerged vegetation; they hatch in about 3 to 6 days (Behler and King, 1979; Martof, 1956a; Ryan, 1953). One to two clutches are laid per year (Wells, 1976). Mean clutch size was reported as 4100 eggs (range, 3800-4300 eggs) in south Michigan (Martof, 1956a). In shallow ponds of New York clutch sizes ranged from 1000 to 7000 (Wells, 1976) and 3500 to 4000 (Wright, 1914). Eggs are incubated only 3 to 6 days (Babbit, 1937; Ryan, 1953).

In the southern part of their range, green frog tadpoles metamorphose into frogs in the same season in which they hatched, while in the northern part, 1 or 2 years pass before metamorphosis (Martof, 1956b). Tadpoles that hatch from egg masses laid in the spring usually metamorphose that fall, while those hatching from summer-laid eggs typically overwinter as larvae and metamorphose the following spring (Pough and Kamel, 1984). Ryan (1953) found that most tadpoles are 2.6 to 3.8 cm SVL at the time of transformation. Those that transform in late June or early July grow rapidly, adding 1.4 to 2.0 cm SVL in the first 2 months and 0.4 to 0.7 cm SVL more before hibernation. Tadpoles that transform at approximately 3.1 cm SVL may reach between 5.0 and 5.8 cm SVL before hibernation (Ryan, 1953). Newly transformed frogs often move from lakes and ponds where they were tadpoles to shallow stream banks, usually during periods of rain (Martof, 1953b).

Behavior and Social Organization

Although adults aggregate during the breeding season, they are solitary during non-breeding periods (Smith, 1956). Martof (1953b) found that the green frog's activity period varies by frog size, with larger frogs being primarily nocturnal, small frogs being diurnal, and middle-sized frogs (5 to 7 cm SVL) being equally active during day and night. Adult green frogs overwinter by hibernating underground or underwater from fall to spring (Ryan, 1953). Martof (1956a) observed frogs hibernating in mud and debris at the bottom of streams approximately 1 m deep. Jenssen and Klimstra (1966) noted that adults usually hibernate in restricted chambers within rock piles or beneath plant debris, while juveniles are more often found in locations with access to passing prey. The frogs begin emerging when the mean daily temperature is about 4.4 °C and the maximum temperature is about 15.6 °C for 3 to 4 days (Martof, 1953b). Juvenile frogs enter and exit hibernation after adult frogs (Martof, 1956a). Martof (1956a) and Ryan (1953) reported that hibernation begins in October or November and ends in March or April.

3.4.8 Bullfrog (*Rana catesbeiana*)[1]

Bullfrogs are in the order Anura, family Ranidae. These are typical frogs with adults being truly amphibious. They tend to live at the edge of water bodies and enter the water to catch

[1] All data from EPA (1993). Text modified to be consistent with the format presented in Sample et al. (1997a)

prey, to flee danger, and to spawn (Behler and King, 1979). This profile covers large ranids. Medium-sized ranids are covered in the previous profile.

Distribution

The bullfrog's natural range includes the eastern and central United States and southeastern Canada; however, it has been introduced in many areas in the western United States and other parts of North America. It is continuing to expand its range, apparently at the expense of several native species in many locations (Bury and Whelan, 1984). There are no subspecies for the bullfrog.

Body Size and Weight

The bullfrog is the largest North American ranid. Adults usually range between 9 and 15 cm in length from snout-to-vent length (SVL) and exceptional individuals can reach one half kilogram or more in weight (Conant and Collins, 1991; Durham and Bennett, 1963). Males are usually smaller than females (Smith, 1961). Frogs exhibit indeterminate growth, and bullfrogs continue to increase in size for at least 6 years after metamorphosis (Durham and Bennett, 1963; Howard, 1981a). Hutchinson et al. (1968) developed an allometric equation relating bullfrog surface area (SA in cm) to body weight (Wt in grams):

$$SA = 0.953\ Wt^{0.725}.$$

TABLE 3-115
Body Weights (g) of the Bullfrog (*Rana catesbeiana*)

Location	Sex/Age	Mean	Range	Reference
New Brunswick, Canada	Both/juveniles and adults	142.8 ± 77.4 SD	9.5 - 274.0	McAlpine and Dilworth, 1989
Central Arkansas	Both/adults	249		McKamie and Heidt, 1974
Kentucky	NS/young tadpole	2.0 ± 1.1 SD		Viparina and Just, 1975
	NS/ 1- yr tadpole	35.7 ± 5.2 SD		
Louisiana/lab	NS /post-emergence			Modzelewski and Culley, 1974
	1 month	18	13 - 42	
	2 month	30	19 - 52	
	3 month	42	27 - 77	
	4 month	56	41 - 101	
ec Illinois	Both/at metamorphosis	9		Durham and Bennett, 1963
	Both/1 year	91		
	Both/2 year	210		
	Both/3 year	240		
	Both/4 year	260		
	Both/5 year	290		
	Both/6 year	360		

Food Habits and Diet Composition

Adult bullfrogs are indiscriminate and aggressive predators, feeding at the edge of the water and among water weeds on any available small animals, including insects, crayfish, other frogs and tadpoles, minnows, snails, young turtles, and occasionally small birds, small mammals, and young snakes (Behler and King, 1979; DeGraaf and Rudis, 1983; Korschgen and Baskett, 1963). Bullfrogs often focus on locally abundant foods (e. g., cicadas, meadow voles) (Korschgen and Baskett, 1963). Crustaceans and insects probably make up the bulk of the diet in most areas (Carpenter and Morrison, 1973; Fulk and Whitaker, 1968; Smith, 1961; Tyler and Hoestenbach, 1979). Bullfrog tadpoles consume primarily aquatic plant material and some invertebrates, but also scavenge dead fish and eat live or dead tadpoles and eggs (Bury and Whelan, 1984; Ehrlich, 1979).

TABLE 3-116
Dietary composition of the bullfrog (*Rana catesbeiana)*

Location/Habitat	Prey Taxa	Spring	Summer	Fall	Reference
Kentucky/NS	Adults:				Bush, 1959
	Decapoda-Astacidae		47.7		
	Lepidoptera		19.0		(percent wet volume; stomach contents)
	Coleoptera		16.0		
	(Lampryidae)		(5.8)		
	(Chrysomelidae)		(5.8)		
	(Crabidae)		(4.1)		
	Pulmonata-Zonitidae		8.3		
	Chilipoda		7.7		
	Sand, rock, gravel		1.2		
New York/mountain lake	Adults:				Stewart and Sandison, 1973
	Plant		19.7		
	Animal		65.2		(percent volume; stomach contents)
	(Odonata)		(8.8)		
	(Coleoptera)		(15.8)		
	(Hemiptera)		(0.5)		
	(Hymenoptera)		(2.2)		
	(Amphibia)		(26.4)		
	Unaccounted		15.1		

TABLE 3-116
Dietary composition of the bullfrog (*Rana catesbeiana)*

Location/Habitat	Prey Taxa	Spring	Summer	Fall	Reference
Missouri/minnow pond	Adults:				Corse and Metter, 1980
	Frogs	35	33	39	
	Tadpoles	8	11	0	(number of items found; stomach contents)
	Shiners	305	157	25	
	Other fish	7	2	5	
	Gastropoda	55	70	26	
	Crayfish	22	162	18	
	Other crustacea	71	42	47	
	Arachnida	3	23	3	
	Coleoptera	31	33	15	
	Diptera (larvae)	2	7	0	
	Hemiptera	41	43	16	

Food Consumption Rate

Modzelewski and Cully (1974) determined the mean food ingestion rates for different weight classes of bullfrogs in Louisiana at temperatures between 24 and 27 °C:

Weight (g)	g/g BW/day
13 – 42	0.071
18 - 52	0.059
28 – 77	0.040
40 – 100	0.033

Water Consumption Rate

No data concerning water consumption in bullfrogs were available in the literature.

Soil Ingestion

Bush (1959) recorded sand, rock and gravel as 1.2 percent of the bullfrog diet.

Respiration Rate

No data concerning inhalation rates in bullfrogs were available in the literature.

Metabolism

The basal metabolic rates were estimated using an equation from Robinson et al. (1983) and assuming a temperature of 20 °C. Pre-metamorphosis bullfrogs, (2 months old; 30g) were estimated to have a rate of 9.1 kcal/kg bW/day based on body weights from Modzelewski and Cully (1974). One year old post-metamorphosis frogs (91 g) were estimated at 7.0 kcal/kg BW/day based on body weights from Durham and Bennett (1963) and Farrar and Dupre (1983). Both Juvenile and adults (143 g) were estimated to have a mean rate of 6.3 kcal/kg BW/day based on body weights from McAlpine and Dilworth (1989). Adults of both sexes (249 g) were estimated to have a mean rate of 5.5 kcal/kg BW/day based on body weights from McKamine and Heidt (1974).

Burggren et al. (1983) measured the metabolic rate (2.6 $\pm$ 0.2 SE L O_2/kg BW/day) for tadpoles held in the laboratory at 25 °C. In contrast, resting adults at 5 °C had a mean metabolic rate of 1.0 L O_2/kg BW/day (range, 0.31-2.3; Hutchinson et al., 1968). The metabolic rate of bullfrogs increases with increasing body temperature. Between 15 and 25 °C, the Q_{10} for oxygen consumption is 1.87; between 25 and 33 °C, the Q_{10} is 2.41 (Burggren et al., 1983).

Habitat Requirements

Adult bullfrogs live at the edges of ponds, lakes, and slow-moving streams large enough to avoid crowding and with sufficient vegetation to provide easily accessible cover (Behler and King, 1979). Small streams are used when better habitat is lacking (Conant and Collins, 1991). Bullfrogs require permanent bodies of water, because the tadpoles generally require 1 or more years to develop prior to metamorphosis (Howard, 1981b). Small frogs favor areas of very shallow water where short grasses or other vegetation or debris offer cover (Durham and Bennett, 1963). Larger bullfrogs seem to avoid such areas (Durham and Bennett, 1963). Tadpoles tend to congregate around green plants (Jaeger and Hailman, 1976, cited in Bury and Whelan, 1984).

Home Range

The bullfrog home range includes its foraging areas and refuges in and around aquatic environments. Home range size decreases with increasing bullfrog density, and males tend to use larger home ranges than females (Currie and Bellis, 1969). Bullfrogs tend to stay in the same pools throughout the summer months if the water level is stable (Raney, 1940, cited in DeGraaf and Rudis, 1983). During the breeding season, adult males establish territories that they defend against conspecific males (Emlen, 1968). During the non-breeding season, Currie and Bellis (1969) found no evidence of territorial defense. Males often do not return to the same pond the following spring (Durham and Bennett, 1963). In ponds in Ontario home ranges for male and female non-breeding adults were 2.9 (range, 0.76-11.3 ha) and 2.4 ha (range, 0.61-10.2 ha), respectively (Currie and Bellis, 1969). In Michigan, territories for males were estimated to be 2.7 ha (Emlen, 1968).

Population Density

During the breeding season, each breeding male bullfrog may defend a few meters of shoreline (Currie and Bellis, 1969; Emlen, 1968). The densities of females and non-breeding males vary with time of day and season and are difficult to estimate. Tadpoles can be present locally in extremely high densities (Cecil and Just, 1979). Estimates of population densities in Ontario were 1,376 frogs/ha in 1960 and 892 frogs/ha in 1961 (Currie and Bellis, 1969). Population densities for tadpoles in Kentucky were 130,000 per ha in November, 69,000 per ha in March and 16,000 per ha in May (Cecil and Just, 1979).

Population Dynamics/Survival

Sexual maturity is attained in about 1 to 3 years after metamorphosis, depending on latitude (Howard, 1978a; Raney and Ingram, 1941, cited in Bury and Whelan, 1984). Only females that are at least 2 years past metamorphosis mate during the early breeding season; males and females 1 year past metamorphosis may breed during the later breeding periods (Howard, 1978a, 1981b). Also, some older females have been observed to mate and to lay a second clutch during the later breeding period (Howard, 1978a). Willis et al. (1956) estimated the minimum breeding length for females in Missouri to be 123 to 125 mm SVL. Mortality of tadpoles is high (Cecil and Just, 1979), and adult frogs are unlikely to live beyond 5 to 8 years post-metamorphosis (Howard, 1978b). In some areas, snapping turtles may be responsible for a large component of adult bullfrog mortality (Howard, 1981a). Annual mortality rates in Michigan ponds as reported by Howard (1984) were 58 percent for males from 1 to 3 years, 48 percent for males from 3 to 4 years, and 77 percent for males from 4 to 5 years. Cecil and Just (1979) reported mortality rates for tadpoles (to metamorphosis) from 82.4 to 88.2 percent (mean, 85.5 percent) in shallow ponds of Kentucky.

Reproduction/Breeding

Bullfrogs spawn at night close to shorelines in areas sheltered by shrubs (Raney, 1940, cited in DeGraaf and Rudis, 1983). The timing and duration of the breeding season varies depending on the location. In the southern states, the breeding season extends from spring to fall, whereas in the northern states, it is restricted to late spring and summer (Behler and King, 1979). Males tend to be territorial during the breeding season, defending their calling posts and oviposition sites (i.e., submerged vegetation near shore) (Howard, 1978b; Ryan, 1980). Female visits to the pond tend to be brief and sporadic (Emlen, 1976). Some males mate with several females whereas others, usually younger and smaller males, may not breed at all in a given year (DeGraaf and Rudis, 1983). Females attach their eggs, contained in floating films of jelly, to submerged vegetation (Behler and King, 1979).

Emlen (1977) observed that 93 percent of females in a Michigan pond laid one clutch of eggs, while only 7 percent of these laid two clutches. Females usually lay from 7,000 to 20,000 eggs per clutch, with a range of 10,000 to 20,000 eggs reported for Kansas bullfrogs (Smith, 1956) and a mean of 7,360 + 741.7 SE eggs reported for New Jersey bullfrogs (Ryan, 1980).

Eggs hatch in 2 to 5 days (Clarkson and DeVos, 1986; Smith, 1956). Temperatures above 32°C have been shown to cause abnormalities in tadpoles and above 35.9 C to kill embryos (Howard, 1978a). Tadpole growth rates increase with increasing oxygen levels, food availability, and water temperature (Bury and Whelan, 1984). Tadpole gill ventilation at 20 C can generate a branchial water flow of almost 0.3 ml/g-min (Burggren and West, 1982). Metamorphosis from a tadpole to a frog can occur as early as 4 to 6 months in the southern parts of its range; however, most tadpoles metamorphose from 1 to 3 years after hatching, depending on latitude and temperature (DeGraaf and Rudis, 1983; Martof et al., 1980).

Behavior and Social Organization

Outside of the breeding season, adults are rather solitary occupying their own part of a stream or pond (Smith, 1961). Bullfrogs thermoregulate behaviorally by positioning themselves relative to the sun and by entering or leaving the water (Lillywhite, 1970). In one study, body temperatures measured in bullfrogs during their normal daily activities averaged 30 °C and ranged from 26 to 33 °C (Lillywhite, 1970). At night, their body temperatures were found to range between 14.4 and 24.9 °C (Lillywhite, 1970). Tadpoles also select relatively warm areas, 24 to 30 °C (Bury and Whelan, 1984). Despite this narrow range of temperatures in which bullfrogs normally maintain themselves, they are not immobilized by moderately lower temperatures (Lillywhite, 1970).

Most bullfrogs hibernate in mud and leaves under water beginning in the fall, but some bullfrogs in the southern states may be active year round (Bury and Whelan, 1984). They emerge sometime in the spring, usually when air temperatures are about 19 to 24 °C and water temperatures are at least 13 to 14 °C (Wright, 1914; Willis et al., 1956). Bullfrogs emerge from hibernation later than other ranid species (Ryan, 1953). Both Durham and Bennett (1963) and Willis et al. (1956) reported hibernation beginning in October and ending in March.

3.5 Quality Control Review for Wildlife Exposure Parameters

Quality control for the species accounts was conducted in two parts: 1) verification of data incorporated from previously published species accounts and 2) review of the 11 new species accounts by a senior CH2M HILL biologist.

Existing species accounts were presented in the *Wildlife Exposures Factors Handbook* (EPA, 1993) and in *Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants* (Sample et al., 1997a). The information in EPA (1993) was converted to the format of Sample et al. (1997a), which consisted of brief summaries of the life histories of each species. Life history data included distribution, body size and weight, food habits and diet composition, food consumption rate, water consumption rate, soil ingestion, respiration rate, metabolism, habitat requirements, home range, population density, population dynamics/survival, reproduction/breeding, behavior and social organization. This conversion required major rearranging of text and input of information contained in the EPA (1993) tables. Additionally, in cases where literature-derived food consumption, water consumption, soil ingestion, and respiration rates were lacking, these rates were estimated using equations presented in Sample et al. (1997a). A minimum of 10 percent (often 50-100%) of all data input from the EPA (1993) tables and all calculations were checked. Although infrequent, the most common quality control findings were typographical and unit errors. All errors were corrected. The text from Sample et al., (1997a) was imported directly; therefore, it was only briefly reviewed to check for conversion problems.

New species accounts were developed from the literature for 11 wildlife species likely to occur at U.S. Army installations. These included the life history data as described above, as well as calculations for food consumption, water consumption, soil ingestion, and respiration rates in the absence of literature-derived values. All species accounts were reviewed by a senior CH2M Hill biologist. These accounts were edited, calculations were checked, and summary tables were checked against the original literature data. Errors were infrequent; however, some quality control errors were found. The most common errors were typographical or grammatical. All errors were corrected.

SECTION 4
Bioaccumulation Parameters

To estimate the magnitude of contaminant exposure that wildlife may experience, contaminant concentrations in food items preferred by endpoint species are needed. These data may be acquired either by direct measurement or estimation.

Direct measurement consists of the collection and analysis of contaminant concentrations in food items. Because direct measurement provides information on the actual contaminant loading in on-site biota, this approach contributes the least uncertainty to exposure estimates and is therefore the preferred approach. For various reasons however (biota phenology incompatible with sampling schedule; insufficient time, personnel, or finances to support field sampling, etc.), direct measurement of contaminant concentrations in biota may not be feasible. When direct measurement of contaminants in biota are not possible, estimation is the only alternative.

Contaminant loads in biota may be estimated using a variety of methods, ranging from mechanistic process models to simple, empirical uptake factors. While mechanistic models for estimation of contaminant concentrations in biota may give more accurate estimates than uptake factors, they generally require considerable information, much of which may not be available in a risk assessment context. Examples of complex contaminant uptake models for plants and fish are presented in Lindstrom et al. (1991) and Thomann and Connolly (1984), respectively. Because of their data requirements, complex models are generally taxa- and location-specific and may not be widely applicable.

The simplest model for estimation of contaminant loads in biota is uptake factors. Uptake factors consist of ratios of the concentration of a given contaminant in biota to that in the abiotic media. (The model assumes that exposure to the food item is primarily from contaminants in the abiotic media) The concentration in biota is estimated by multiplying the abiotic concentration by the uptake factor. Because contaminant uptake is influenced by characteristics of the organism and by the properties of the contaminant, separate uptake factors are recommended for each contaminant and taxonomic group being considered. Bioavailability of contaminants for uptake can also be influenced by soil conditions. For example, Corp and Morgan (1991) observed that while high amounts of soil organic matter reduced the bioavailability of lead to earthworms, low soil pH increased bioavailability.

Uncertainty associated with the use of uptake factors may be high. The use of uptake factors depends on the assumption that the concentration of chemicals in organisms is a linear, no threshold function of concentrations in media. However, it has been suggested that this assumption is incorrect and bioaccumulation (at least for soil-to-biota uptake of inorganic analytes) is non-linear with respect to media concentration (Alsop et al., 1996; Sample et al., 1998a, 1999). Therefore, the use of uptake factors is likely to overestimate the actual concentrations in the biota.

Empirical regression models, which are derived using biota and chemical data from contaminated sites, are generally preferable to simple uptake factors. This is primarily because soil parameters, which can affect bioaccumulation (e.g., pH, cation exchange capacity, and organic matter), can be included in regression models. Additionally, regression models explain more of the variability of the data and address the nonlinearity of bioaccumulation (Suter et al., 2000). Generally, the data is log-transformed and simple linear regression analysis is used. The regression model for transformed data is expressed as:

$$\log(\text{biota}) = B_0 + B_1 [\log(\text{media})]$$

where,

$\log(\text{biota})$ = estimated log-transformed biota concentration,

$\log(\text{media})$ = measured log-transformed concentration in media,

B_0 = intercept,

and

B_1 = slope.

Log transformations can either be $\log_{10}$ or natural log.

In this section, methods and models for estimating contaminant concentrations in aquatic organisms, earthworms, plants, and small mammals, as well as existing and newly developed bioaccumulation data are presented. Analytes evaluated were those relevant to U.S. Army installations and include metals/inorganics, explosives, chlorinated organics, polycyclic aromatic hydrocarbons (PAHs), and uranium (Table 4-1).

TABLE 4-1
List of U.S. Army Relevant Analytes for Which There Are Either Existing or New Empirically-Derived Bioaccumulation Data

Analytes	Existing Data	New Data
Explosives		
Cyclotrimethylenetrinitramine (RDX)		Root
		Leaf
2,4,6-Trinitrotoluene (TNT)		Root
		Leaf
2-Amino 4,5-dinitrotoluene (2-ADNT)		Root
		Leaf
4-Amino 2,6-dinitrotoluene (4-ADNT)		Root
		Leaf
Inorganics		
Arsenic	Plants	Root
	Earthworms	Leaf
	Small Mammals	Fruit
	Benthic Invertebrates	Seed
	Aquatic Organisms	Whole Plant
		Terrestrial Invertebrates

TABLE 4-1
List of U.S. Army Relevant Analytes for Which There Are Either Existing or New Empirically-Derived Bioaccumulation Data

Analytes	Existing Data	New Data
Cadmium	Plants	Root
	Earthworms	Leaf
	Small Mammals	Terrestrial Invertebrates
	Benthic Invertebrates	
	Aquatic Organisms	
Cobalt	Plants	Leaf
	Earthworms	Seed
	Small Mammals	Terrestrial Invertebrates
Copper	Plants	Root
	Earthworms	Leaf
	Small Mammals	Stem
	Benthic Invertebrates	Fruit
	Aquatic Organisms	Seed
		Whole Plant
		Terrestrial Invertebrates
Lead	Plants	Leaf
	Earthworms	Fruit
	Small Mammals	Seed
	Benthic Invertebrates	Whole Plant
	Aquatic Organisms	Terrestrial Invertebrates
Mercury (elemental)	Plants	Leaf
	Earthworms	Seed
	Small Mammals	Terrestrial Invertebrates
	Benthic Invertebrates	
Mercury (methyl)	Aquatic Organisms	
Selenium	Plants	Root
	Earthworms	Leaf
	Small Mammals	Stem
	Aquatic Organisms	Fruit
		Seed
		Terrestrial Invertebrates
Uranium	Earthworms	Root
		Leaf
		Stem
		Fruit
		Seed

TABLE 4-1
List of U.S. Army Relevant Analytes for Which There Are Either Existing or New Empirically-Derived Bioaccumulation Data

Analytes	Existing Data	New Data
Vanadium	Earthworms	Root
	Small Mammals	Leaf
		Seed
		Terrestrial Invertebrates
Zinc	Plants	Root
	Earthworms	Leaf
	Small Mammals	Fruit
	Benthic Invertebrates	Seed
	Aquatic Organisms	Whole Plant
		Terrestrial Invertebrates
Organics		
DDT, DDD, DDE	Plants	
	Small Mammals	
Dieldrin	Plants	
	Earthworms	
	Small Mammals	
PCBs (total)	Earthworms	
	Benthic Invertebrates	
PAHs	Plants	Root
		Leaf

4.1 Existing Models

Multiplying factors and water-to-biota bioaccumulation models (BAFs) have been compiled from various sources as indicated in Section 4.1.1. Soil-to-biota bioaccumulation models, both as simple BAFs or as regression models, have recently been developed from published data for earthworms, terrestrial plants and small mammals (e.g., Sample et al., 1999; Sample et al., 1998a; Sample et al., 1998b; and Bechtel-Jacobs, 1998a; EPA, 2000). Additionally, biota sediment accumulation models (BSAFs or regression models) have been developed from published data for benthic invertebrates (Bechtel-Jacobs, 1998b). Bioaccumulation models presented provide the primary source for estimation of concentrations of a variety of analytes in aquatic organisms, as well as of inorganic contaminants in earthworms, terrestrial plants, small mammals, and benthic invertebrates. If both BAFs and regression models were available for a given contaminant, the regression model was selected for application provided the model was significant (i.e., the slope differed significantly [$p \leq 0.05$] from 0) and the coefficient of determination (r^2) was greater than or equal to 0.2. If neither of these criteria were met, the median BAF or BSAF was used to estimate bioaccumulation (Table 4-2). Multiplying factors and BAFs for aquatic organisms are presented in Section 4.1.1 (Tables 4-3 and 4-4, respectively).

Bioaccumulation models (BAFs, BSAFs, or regression models) generally are not available for organics; however, models have been developed to estimate bioaccumulation in aquatic organisms, earthworms, terrestrial plants, and small mammals based on the octanol-water partition coefficient (K_{ow}) of the organic analyte. It should be noted that all BAF, regression, and octonal-partition coefficient models estimate tissue concentration in mg/kg of dry weight. Because wildlife do not consume dry food, these values must be converted to mg/kg of wet weight before they are employed in exposure estimation:

$$C_{wet} = C_{dry} * P_{dry},$$

where,

C_{wet} – wet weight concentration (mg/kg),

C_{dry} = dry weight concentration (mg/kg),

and

P_{dry} = proportion dry matter content of food item (see Table 3-4).

A description of these models and their assumptions follows.

Table 4-2

Summary of Existing Bioaccumulation Models for Food Items for Wildlife Species Relevant to U.S. Army Installationns - Highlighted Values Represent Recommended Bioaccumulation Data

				Summary Statistics for BAFs					Parameters for log-linear uptake model[1]					
Taxa	Analyte	Trophic Group or Depuration Status	Transfer type	N	Minimum	Median	Maximum	Trophic Group or Depuration Status	N	Slope	Intercept	r-square	p (model)	reference
Plants	Antimony	NA	soil-to-biota	17	0.003	0.037	0.22	NA	17	0.937	-3.233	0.79	0.0001	EPA 2000
Plants	Arsenic	NA	soil-to-biota	122	0.00006	0.03752	9.0741	NA	122	0.564	-1.991	0.15	0.0001	Bechtel-Jacobs 1998a
Plants	Barium	NA	soil-to-biota	28	0.036	0.156	0.92	NA	.	.	.	.	.	Bechtel-Jacobs 1998a
Plants	Beryllium	NA	soil-to-biota			0.01								Baes et al. 1984
Plants	Cadmium	NA	soil-to-biota	207	0.0087	0.58571	22.8788	NA	207	0.546	-0.475	0.45	0.0001	Bechtel-Jacobs 1998a
Plants	Chromium	NA	soil-to-biota	28	0.021	0.041	0.48	NA	.	.	.	.	.	Bechtel-Jacobs 1998a
Plants	Cobalt	NA	soil-to-biota	28	0.0019	0.0075	0.045	NA	.	.	.	.	.	Bechtel-Jacobs 1998a
Plants	Copper	NA	soil-to-biota	180	0.0011	0.12432	7.4	NA	180	0.394	0.668	0.31	0.0001	Bechtel-Jacobs 1998a
Plants	Lead	NA	soil-to-biota	189	0.00011	0.0388	10.6011	NA	189	0.561	-1.328	0.24	0.0001	Bechtel-Jacobs 1998a
Plants	Mercury (inorganic)	NA	soil-to-biota	145	0.00145	0.652	12.23	NA	82	0.641	-4.186	0.677	0.0001	Bechtel-Jacobs 1998a
Plants	Manganese	NA	soil-to-biota	28	0.0199	0.079	0.433	NA	.	.	.	.	.	Bechtel-Jacobs 1998a
Plants	Nickel	NA	soil-to-biota	111	0.00217	0.01786	22.2143	NA	111	0.748	-2.223	0.37	0.0001	Bechtel-Jacobs 1998a
Plants	Selenium	NA	soil-to-biota	158	0.02	0.67189	77	NA	158	1.104	-0.677	0.63	0.0001	Bechtel-Jacobs 1998a
Plants	Silver	NA	soil-to-biota	10	0.0029	0.014	0.04	NA	.	.	.	.	.	Bechtel-Jacobs 1998a
Plants	Zinc	NA	soil-to-biota	220	0.00855	0.36616	34.2857	NA	220	0.554	1.575	0.4	0.0001	Bechtel-Jacobs 1998a
Plants	Dieldrin	NA	soil-to-biota	41	0.00855	0.024	1.64	NA	41	0.841	-3.271	0.24	0.001	EPA 2000
Plants	DDT	NA	soil-to-biota	7	0.00035	0.028	0.08	NA						EPA 2000
Plants	DDD	NA	*soil-to-biota*	*7*	*0.00035*	*0.028*	*0.08*	NA						see footnote 3
Plants	DDE	NA	soil-to-biota	3	0.075	0.136	0.62	NA						EPA 2000
Plants	PAHs													
	Pentachlorophenol	NA	soil-to-biota	3600	4.70E-03	9.615071	25277.54	NA						Modeled from Kow, EPA 2000
	Anthracene	NA	soil-to-biota	8	0.16292	1	3.1	NA	8	0.867	0.079	0.62	0.02	EPA 2000
	Benzo(a)anthracene	NA	soil-to-biota	1	0.53704	0.537	0.54							EPA 2000
	Benzo(a)pyrene	NA	soil-to-biota	7	0.01964	0.066	0.2	NA	7	0.635	-2.053	0.61	0.04	EPA 2000
	Benzo(b)fluoranthene	NA	soil-to-biota	6	0.01627	0.173	0.48							EPA 2000
	Benzo(e)pyrene	NA	soil-to-biota	4	0.10169	0.19	0.27							EPA 2000
	Benzo(ghi)perylene	NA	soil-to-biota	7	0.05278	0.131	1.31	NA	7	1.299	-2.565	0.81	0.006	EPA 2000
	Benzo(k)fluoranthene	NA	soil-to-biota	4	0.08	0.255	0.36							EPA 2000
	Chrysene	NA	soil-to-biota	4	0.16216	0.784	1.05							EPA 2000
	Coronene	NA	soil-to-biota	3	0.5787	0.588	4.61							EPA 2000
	Dibenz(ah)anthracene	NA	soil-to-biota	4	0.06977	0.128	0.23							EPA 2000
	Fluoranthene	NA	soil-to-biota	7	0.26838	2.466	6.03							EPA 2000
	Fluorene	NA	soil-to-biota	4	0.01089	0.041	0.06							EPA 2000
	Indeno(123 cd)pyrene	NA	soil-to-biota	2	0.07143	0.11	0.15							EPA 2000
	Naphthlene	NA	soil-to-biota	7	0.29412	1.059	4.19							EPA 2000
	Phenanthrene	NA	soil-to-biota	7	0.69243	3.837	7.92							EPA 2000
	Pyrene	NA	soil-to-biota	7	0.19324	1.852	3.7							EPA 2000
Plants	TNT	NA	soil-to-biota	3600	2.09E-03	5.066329	8714.967	NA						Modeled from Kow, EPA 2000
Plants	RDX	NA	soil-to-biota	3600	1.39E-04	0.2418139	553.3746	NA						Modeled from Kow, EPA 2000
Earthworms	Antimony	NA		.	.	.	.	NA	.	.	.	.	.	
Earthworms	Arsenic	NA	soil-to-biota	53	0.006	0.224	0.925	NA	53	0.706	-1.421	0.26	0.0001	Sample et al. 1999
Earthworms	Barium	NA	soil-to-biota	20	0.005	0.091	0.31	NA	.	.	.	.	.	Sample et al. 1998a
Earthworms	Beryllium	NA	soil-to-biota	12	0	0.045	1.429	NA	.	.	.	.	.	Sample et al. 1998a
Earthworms	Cadmium	NA	soil-to-biota	226	0.253	7.708	190	NA	226	0.795	2.114	0.67	0.0001	Sample et al. 1999
Earthworms	Chromium	NA	soil-to-biota	67	0.021	0.306	11.416	NA	67	-0.067	2.481	0.0026	0.68	Sample et al. 1999
Earthworms	Cobalt	NA	soil-to-biota	17	0.031	0.122	0.321	NA	.	.	.	.	.	Sample et al. 1998a
Earthworms	Copper	NA	soil-to-biota	197	0.002	0.515	5.492	NA	197	0.264	1.675	0.18	0.0001	Sample et al. 1999
Earthworms	Lead	NA	soil-to-biota	245	0	0.266	228.261	NA	245	0.807	-0.218	0.58	0.0001	Sample et al. 1999
Earthworms	Manganese	NA	soil-to-biota	36	0.012	0.054	0.228	NA	36	0.682	-0.809	0.34	0.0002	Sample et al. 1999
Earthworms	Mercury (inorganic)	NA	soil-to-biota	30	0.03	1.693	33							Sample et al. 1998a
Earthworms	Nickel	NA	soil-to-biota	31	0.033	1.059	7.802	NA	31	-0.26	3.677	0.06	0.19	Sample et al. 1999
Earthworms	Selenium	NA	soil-to-biota	14	0.3	0.985	13.733	NA	13	0.733	-0.075	0.43	0.016	Sample et al. 1999
Earthworms	Silver	NA	soil-to-biota	10	0.001	2.045	19.5	NA	.	.	.	.	.	Sample et al. 1998a

Table 4-2

Summary of Existing Bioaccumulation Models for Food Items for Wildlife Species Relevant to U.S. Army Installationns - Highlighted Values Represent Recommended Bioaccumulation Data

				Summary Statistics for BAFs					Parameters for log-linear uptake model[1]					
Taxa	**Analyte**	**Trophic Group or Depuration Status**	**Transfer type**	**N**	**Minimum**	**Median**	**Maximum**	**Trophic Group or Depuration Status**	**N**	**Slope**	**Intercept**	**r-square**	**p (model)**	**reference**
Earthworms	Vanadium	NA	soil-to-biota	6	0.0001	0.042	0.088							Sample et al. 1998a
Earthworms	Zinc	NA	soil-to-biota	244	0.025	3.201	49.51	NA	244	0.328	4.449	0.45	0.0001	Sample et al. 1999
Earthworms	Uranium	NA	soil-to-biota	2	0.003	0.033	0.063							Sample et al. 1998a
Earthworms	PCBs	NA	soil-to-biota	32	0.0001	6.667	65.227	NA	31	1.361	1.41	0.89	0.0001	Sample et al. 1998a
Earthworms	TCDD	NA	soil-to-biota	19	1.191	11.011	42.068	NA	19	1.182	3.533	0.94	0.001	Sample et al. 1998a
Earthworms	Dieldrin	NA	soil-to-biota	6300	1.73	267.08	770000.00	NA	.	.	.	.	.	Modeled from Kow, EPA 2000
Earthworms	DDT	NA	soil-to-biota	6300	0.59	116.61	37000.00	NA	.	.	.	.	.	Modeled from Kow, EPA 2000
Earthworms	DDD	NA	soil-to-biota	6300	0.27	67.55	40000.00	NA	.	.	.	.	.	Modeled from Kow, EPA 2000
Earthworms	DDE	NA	soil-to-biota	6300	0.12	73.04	38000.00	NA	.	.	.	.	.	Modeled from Kow, EPA 2000
Earthworms	Pentachlorophenol	NA	soil-to-biota	6300	0.23	74.68	49000.00	NA	.	.	.	.	.	Modeled from Kow, EPA 2000
Earthworms	PAHs	NA	soil-to-biota	6300	0.08	50.61	53000.00	NA	.	.	.	.	.	Modeled from Kow, EPA 2000
	Acenaphthene	NA	soil-to-biota	6300	0.08	38.75	10997.33	NA	.	.	.	.	.	Modeled from Kow, EPA 2000
	Anthracene	NA	soil-to-biota	6300	0.14	44.00	6535.99	NA	.	.	.	.	.	Modeled from Kow, EPA 2000
	Benzo(a)anthracene	NA	soil-to-biota	6300	0.03	34.45	28284.23	NA	.	.	.	.	.	Modeled from Kow, EPA 2000
	Benzo(b)fluoranthene	NA	soil-to-biota	6300	0.10	72.78	52905.02	NA	.	.	.	.	.	Modeled from Kow, EPA 2000
	Benzo(k)fluoranthene	NA	soil-to-biota	6300	0.08	71.30	27972.71	NA	.	.	.	.	.	Modeled from Kow, EPA 2000
	Benzo(ghi)perylene	NA	soil-to-biota	6300	0.35	81.08	24226.89	NA	.	.	.	.	.	Modeled from Kow, EPA 2000
	Benzo(a)pyrene	NA	soil-to-biota	6300	0.14	31.47	11628.95	NA	.	.	.	.	.	Modeled from Kow, EPA 2000
	Chrysene	NA	soil-to-biota	6300	0.10	61.78	15876.65	NA	.	.	.	.	.	Modeled from Kow, EPA 2000
	Dibenzo(ah)anthracene	NA	soil-to-biota	6300	0.21	78.71	11605.75	NA	.	.	.	.	.	Modeled from Kow, EPA 2000
	Naphthalene	NA	soil-to-biota	6300	0.14	50.61	15394.11	NA	.	.	.	.	.	Modeled from Kow, EPA 2000
	Phenanthrene	NA	soil-to-biota	6300	0.08	45.49	11607.82	NA	.	.	.	.	.	Modeled from Kow, EPA 2000
Earthworms	TNT	NA	soil-to-biota	6300	0.02	19.57	5424	NA	.	.	.	.	.	Modeled from Kow, EPA 2000
Earthworms	RDX	NA	soil-to-biota	6300	0.04	9.91	2570	NA	.	.	.	.	.	Modeled from Kow, EPA 2000
Small Mammals	Antimony		diet-to-biota			0.001								Baes et al. 1984
Small Mammals	Arsenic	General	soil-to-biota	72	0	0.0025	0.071	General	60	0.8188	-4.8471	0.52	0.0001	Sample et al. 1998b
Small Mammals	Barium	.	diet-to-biota	.	.	0.001	.	.	.	.	.	.	.	Baes et al. 1984
Small Mammals	Beryllium	.	diet-to-biota	.	.	0.00015	.	.	.	.	.	.	.	Baes et al. 1984
Small Mammals	Cadmium	Herbivore	soil-to-biota	28	0.0153	0.1258	1	Herbivore	28	0.4723	-1.2571	0.64	0.0001	Sample et al. 1998b
Small Mammals	Chromium	General	soil-to-biota	38	0.0314	0.0846	0.8	General	38	0.7338	-1.4599	0.42	0.0001	Sample et al. 1998b
Small Mammals	Cobalt	General	soil-to-biota	15	0.0101	0.0205	0.18	General	15	1.307	-4.4669	0.41	0.01	Sample et al. 1998b
Small Mammals	Copper	General	soil-to-biota	76	0.0044	0.1963	1.398	General	76	0.1444	2.042	0.26	0.0001	Sample et al. 1998b
Small Mammals	Lead	General	soil-to-biota	138	0.0031	0.1054	2.659	General	138	0.4422	0.0761	0.37	0.0001	Sample et al. 1998b
Small Mammals	Manganese	General	soil-to-biota	12	0.0114	0.0205	0.079	.	.	.	.	.	.	Sample et al. 1998b
Small Mammals	Mercury (inorganic)	General	soil-to-biota	18	0.0183	0.0543	1.046							Sample et al. 1998b
Small Mammals	Nickel	General	soil-to-biota	43	0	0.2488	1.143	General	36	0.4658	-0.2462	0.55	0.0001	Sample et al. 1998b
Small Mammals	Selenium	General	soil-to-biota	35	0	0.1619	1.754	General	27	0.3764	-0.4158	0.31	0.0026	Sample et al. 1998b
Small Mammals	Silver	General	soil-to-biota	10	0	0.004	0.81	.	.	.	.	.	.	Sample et al. 1998b
Small Mammals	Vanadium	General	soil-to-biota	12	0.0052	0.0123	0.019							Sample et al. 1998b
Small Mammals	Zinc	Herbivore	soil-to-biota	30	0.00511	0.504	16.3636	Herbivore	30	0.0706	4.3632	0.31	0.0013	Sample et al. 1998b
Small Mammals	TCDD							General	5	1.0993	0.8113	0.92	0.0096	Sample et al. 1998b
Small Mammals	TCDF	General	soil-to-biota	4	0.074	0.1251	0.157							Sample et al. 1998b
Small Mammals	Dieldrin	Beef	diet-to-biota	29	0.35088	0.9091	1.4035							EPA 2000
Small Mammals	DDT	Beef	diet-to-biota	2	0.0188	0.1344	0.25							EPA 2000
Small Mammals	DDD	Beef	diet-to-biota	*2*	*0.0188*	*0.1344*	*0.25*							see footnote 4
Small Mammals	DDE	Beef	diet-to-biota	3	0.0084	0.0294	0.0372							EPA 2000
Small Mammals	Pentachlorophenol	NA	diet-to-biota	NA	.	.	.	chickens[2]		0.00452	0.198	0.837	.	Stedman et al. 1980
Benthic Invertebrates	Arsenic		sediment-to-biota					Non-depurated	49	0.873	-0.572	0.65	0.001	Bechtel-Jacobs 1998b
Benthic Invertebrates	Cadmium		sediment-to-biota					Non-depurated	88	0.668	0.191	0.58	0.001	Bechtel-Jacobs 1998b
Benthic Invertebrates	Chromium		sediment-to-biota					All	34	0.365	0.2092	0.2	0.01	Bechtel-Jacobs 1998b
Benthic Invertebrates	Copper		sediment-to-biota					Non-depurated	74	0.359	1.037	0.54	0.001	Bechtel-Jacobs 1998b
Benthic Invertebrates	Lead		sediment-to-biota					All	114	0.801	-0.776	0.35	0.001	Bechtel-Jacobs 1998b
Benthic Invertebrates	Mercury	All	sediment-to-biota	15	0.286	1.136	3.981							Bechtel-Jacobs 1998b

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				Summary Statistics for BAFs					Parameters for log-linear uptake model[1]					
Taxa	**Analyte**	**Trophic Group or Depuration Status**	**Transfer type**	**N**	**Minimum**	**Median**	**Maximum**	**Trophic Group or Depuration Status**	**N**	**Slope**	**Intercept**	**r-square**	**p (model)**	**reference**
Benthic Invertebrates	Nickel	All	sediment-to-biota	26	0.055	0.486	5.746							Bechtel-Jacobs 1998b
Benthic Invertebrates	Zinc		sediment-to-biota					Non-depurated	84	0.242	1.77	0.33	0.001	Bechtel-Jacobs 1998b
Benthic Invertebrates	PCBs		sediment-to-biota					Benthos	16	1.11	0.59	0.65	0.001	Bechtel-Jacobs 1998b
Benthic Invertebrates	PCBs		sediment-to-biota					Adults	10	0.939	1.6	0.94	0.001	Bechtel-Jacobs 1998b

Notes:

[1] model is of the form: ln (tissue [dry wt.]) = slope*(ln[soil])+ intercept

[2] model is for bioaccumulation into breast muscle and is of the form: tissue [dry wt.] = slope*(diet)+ intercept

[3] Plant bioaccumulation data were unavailable; bioaccumulation data for DDE is assumed to be representative.

[4] Beef bioaccumulation data were unavailable; bioaccumulation data for DDT is assumed to be representative.

4.1.1 Aquatic Organisms

In aquatic organisms, the bioaccumulation factor (BAF) is the ratio of the concentration of a contaminant in tissue (mg/kg) to its concentration in water (mg/L), where both the organism and its prey are exposed, and is expressed as L/kg. BAFs may be predicted by multiplying the bioconcentration factor for the contaminant [bioconcentration factor (BCF), ratio of concentration in food to concentration in water; i.e., (mg/kg)/(mg/L) = L/kg] by the appropriate food chain multiplying factor (FCM) (see Table 4-3). For most inorganic compounds, BCFs and BAFs are assumed to equal; however, an FCM may be applicable for some metals if the organometallic form biomagnifies (EPA 1995a).

TABLE 4-3
Aquatic Food Chain Multiplying Factors[a]

	Prey Trophic Level[b]		
Log K_{ow}	2	3	4
2	1	1.005	1
2.5	1	1.01	1.002
3	1	1.028	1.007
3.1	1	1.034	1.007
3.2	1	1.042	1.009
3.3	1	1.053	1.012
3.4	1	1.067	1.014
3.5	1	1.083	1.019
3.6	1	1.103	1.023
3.7	1	1.128	1.033
3.8	1	1.161	1.042
3.9	1	1.202	1.054
4	1	1.253	1.072
4.1	1	1.315	1.096
4.2	1	1.38	1.13
4.3	1	1.491	1.178
4.4	1	1.614	1.242
4.5	1	1.766	1.334
4.6	1	1.95	1.459
4.7	1	2.175	1.633
4.8	1	2.452	1.871
4.9	1	2.78	2.193
5	1	3.181	2.612

TABLE 4-3
Aquatic Food Chain Multiplying Factors[a]

	Prey Trophic Level[b]		
Log K_{ow}	2	3	4
5.1	1	3.643	3.162
5.2	1	4.188	3.873
5.3	1	4.803	4.742
5.4	1	5.502	5.821
5.5	1	6.266	7.079
5.6	1	7.096	8.551
5.7	1	7.962	10.209
5.8	1	8.841	12.05
5.9	1	9.716	13.964
6	1	10.556	15.996
6.1	1	11.337	17.783
6.2	1	12.064	19.907
6.3	1	12.691	21.677
6.4	1	13.228	23.281
6.5	1	13.662	24.604
6.6	1	13.98	25.645
6.7	1	14.223	26.363
6.8	1	14.355	26.669
6.9	1	14.388	26.669
7	1	14.305	26.242
7.1	1	14.142	25.468
7.2	1	13.852	24.322
7.3	1	13.474	22.856
7.4	1	12.987	21.038
7.5	1	21.517	18.967
7.6	1	11.708	16.749
7.7	1	10.914	14.388
7.8	1	10.069	12.05
7.9	1	9.162	9.84
8	1	8.222	7.798
8.1	1	7.278	6.012

TABLE 4-3
Aquatic Food Chain Multiplying Factors[a]

Log K_{ow}	Prey Trophic Level[b] 2	3	4
8.2	1	6.361	4.519
8.3	1	5.489	3.311
8.4	1	4.683	2.371
8.5	1	3.949	1.663
8.6	1	3.296	1.146
8.7	1	2.732	0.778
8.8	1	2.246	0.521
8.9	1	1.837	0.345
9	1	1.493	0.226

a From EPA 1993b
b Trophic level: 2 = zooplankton; 3 = small fish; 4 = piscivorous fish, including top predators.

In cases where the BCF for a particular compound is not available, it can be estimated from the octanol-water partition coefficient of the compound by the following relationship (Lyman et al. 1982):

$$\log BCF = 0.76 \log K_{ow} - 0.23.$$

The BCF can also be estimated from the water solubility of a compound by the following regression equation (Lyman et al. 1982):

$$\log BCF = 2.791 - 0.564 \log WS$$

where,

WS = water solubility in mg/L water.

Log K_{ow} values, reported or calculated BCF values, and estimated BAF values for chemicals for which benchmarks have been derived are included on Table 4-4. Reported BCFs represent the maximum value listed for fish. An FCM of 1 was applied to all reported BCFs for inorganic compounds (EPA 1993b). Mink, belted kingfisher, great blue heron, and osprey consume 100 percent trophic level 3 fish (EPA 1995c); the trophic level 3 FCM appropriate for the log K_{ow} of the chemical was applied as appropriate. River otter were assumed to consume 80 percent trophic level 3 and 20 percent trophic level for fish (EPA 1995c). To calculate the final piscivore benchmark for river otter, the level 3 BAF was applied to 80 percent of the diet, and the level 4 BAF was applied to the remaining 20 percent.

TABLE 4-4
Octanol-Water Partition Coefficients, Bioconcentration Factors, and Bioaccumulation Factors for Selected Chemicals

Chemical and Form	Log K_{ow}	BCF	Trophic Level 3 FCM	Trophic Level 3 BAF	Trophic Level 4 FCM	Trophic Level 4 BAF	Source[b]
Acetone	-0.24	0.39[a]	1	0.39	1	0.39	EPA 1995d
Aldrin	6.5	51286.14[a]	13.662	700671.22	24.604	1261844.15	EPA 1995d
Aluminum		231	1	231.00	1	231.00	EPA 1988
Antimony		1	1	1.00	1	1.00	EPA 1980a
Aroclor 1016	5.6	10616.96[a]	7.096	75337.92	8.551	90785.59	ATSDR 1989
Aroclor 1242	5.6	10616.96[a]	7.096	75337.92	8.551	90785.59	ATSDR 1989
Aroclor 1248	6.2	30338.91[a]	12.064	366008.63	19.907	603956.72	ATSDR 1989
Aroclor 1254	6.5	51286.14[a]	13.662	1850000.00	24.604	6224000.00	ATSDR 1989, EPA 1995b[c]
Arsenic (arsenite)		17.00	1	17.00	1	17.00	EPA 1984a
Benzene	2.13	24.48[a]	1.005	24.60	1	24.48	EPA 1995d
beta-BHC	3.81	463.02[a]	1.161	537.56	1.042	482.47	EPA 1995d
BHC-mixed isomers	5.89	17636.00[a]	9.716	171351.34	13.964	246269.05	EPA 1995d
Benzo(a)pyrene	6.11	25917.91[a]	11.337	293831.36	17.783	460898.22	EPA 1995d
Beryllium		19.00	1	19.00	1	19.00	EPA 1980b
Bis(2-ethylhexyl)phthalate	7.3	207969.67[a]	13.747	2858959.04	22.856	4753354.75	EPA 1995d
Cadmium		12400.00	1	12400.00	1	12400.00	EPA 1984b
Carbon Tetrachloride	2.73	69.95[a]	1.01	70.65	1.002	70.09	EPA 1995d
Chlordane	6.32	37428.29[a]	12.691	475002.44	21.677	811333.07	EPA 1995d
Chlordecone (kepone)	5.3	6280.58[a]	4.803	30165.64	4.742	29782.53	EPA 1995d
Chloroform	1.92	16.95[a]	1.005	17.04	1	16.95	EPA 1995d
Chromium (Cr+6)		3.00	1	3.00	1	3.00	EPA 1985c
Copper		290.00	1	290.00	1	290.00	EPA 1985d
o-Cresol	1.99	19.16[a]	1.005	19.26	1	19.16	EPA 1995d
Cyanide		0.00	1	0.00	1	0.00	EPA 1985b
DDT(and metabolites)	6.53	54050.54[a]	13.662	1336000.00	24.604	3706000.00	EPA 1995d, EPA 1995b[c]
1,2-Dichloroethane	1.47	7.71[a]	1	7.71	1	7.71	EPA 1995d
1,1-Dichloroethylene	2.13	24.48[a]	1.005	24.60	1	24.48	EPA 1995d
1,2-Dichloroethylene	1.86	15.26[a]	1.006	15.35	1	15.26	EPA 1995d

TABLE 4-4
Octanol-Water Partition Coefficients, Bioconcentration Factors, and Bioaccumulation Factors for Selected Chemicals

Chemical and Form	Log K_{ow}	BCF	Trophic Level 3 FCM	Trophic Level 3 BAF	Trophic Level 4 FCM	Trophic Level 4 BAF	Source[b]
Dieldrin	5.37	7099.05[a]	7.962	56522.61	10.209	72474.16	EPA 1995d
Diethylphthalate	2.5	46.77[a]	1.01	47.24	1.002	46.87	EPA 1995d
Di-n-butyl phthalate	4.61	1877.59[a]	1.95	3661.29	1.459	2739.40	EPA 1995d
1,4-Dioxane	-0.39	0.30[a]	1	0.30	1	0.30	EPA 1995d
Endosulfan	4.1	769.13[a]	1.315	1011.41	1.096	842.97	EPA 1995d
Endrin	5.06	4126.67[a]	3.643	15033.47	3.162	13048.54	EPA 1995d
Ethanol	-0.31	0.34[a]	1	0.34	1	0.34	EPA 1992
Ethyl Acetate	0.69	1.97[a]	1	1.97	1	1.97	EPA 1995d
Formaldehyde	-0.05	0.54[a]	1	0.54	1	0.54	EPA 1995d
Heptachlor	6.26	33697.68[a]	12.691	427657.26	21.677	730464.61	EPA 1995d
Lead		45.00	1	45.00	1	45.00	EPA 1985a
Lindane (Gamma-BHC)	3.73	402.53[a]	1.128	454.06	1.033	415.82	EPA 1995d
Mercury (Methyl Mercury Chloride)				27900.00		140000.00	EPA 1995b[c]
Methanol	-0.71	0.17[a]	1	0.17	1	0.17	EPA 1995d
Methoxychlor	5.08	4273.66[a]	3.643	15568.94	3.162	13513.31	EPA 1995d
Methylene Chloride	1.25	5.25[a]	1	5.25	1	5.25	EPA 1995d
Methyl Ethyl Ketone	0.28	0.96[a]	1	0.96	1	0.96	EPA 1995d
4-Methyl 2-Pentanone	1.19	4.73[a]	1	4.73	1	4.73	EPA 1992
Nickel		106.00	1	106.00	1	106.00	EPA 1986
Pentachloro-nitrobenzene	4.64	1978.79[a]	1.95	3858.64	1.459	2887.06	EPA 1995d
Pentachlorophenol	5.09	1000.00[a]	3.643	3643.00	3.162	3162.00	EPA 1995d
Selenium				2600.00		6800.00	Peterson and Nebeker 1992[c]
2,3,7,8-Tetrachloro-Dibenzodioxin	6.53	54050.54[a]	13.662	172100.00	24.604	264100.00	EPA 1995d,EPA 1995b[c]
1,1,2,2-Tetrachloro-ethylene	2.67	62.98[a]	1.01	63.61	1.002	63.11	EPA 1995d
Thallium		34.00	1	34.00	1	34.00	EPA 1980c
Toluene	2.75	72.44[a]	1.028	74.47	1.007	72.95	EPA 1995d
Toxaphene	5.5	8912.51[a]	6.266	55845.78	7.079	63091.65	EPA 1995d

TABLE 4-4
Octanol-Water Partition Coefficients, Bioconcentration Factors, and Bioaccumulation Factors for Selected Chemicals

Chemical and Form	Log K_{ow}	BCF	Trophic Level 3 FCM	Trophic Level 3 BAF	Trophic Level 4 FCM	Trophic Level 4 BAF	Source[b]
1,1,1-Trichloroethane	2.48	45.16[a]	1.01	45.62	1.002	45.26	EPA 1995d
Trichloroethylene	2.71	67.55[a]	1.01	68.22	1.002	67.68	EPA 1995d
Vinyl Chloride	1.5	8.13[a]	1	8.13	1	8.13	EPA 1995d
Xylene (mixed isomers)	3.2	159.22[a]	1.042	165.91	1.009	160.65	EPA 1995d
Zinc		966.00	1	966.00	1	966.00	EPA 1987

a Values estimated using the following equation: log BCF = 0.76 log Kow - 0.23
b Citation for Kow values unless otherwise noted
a Source for BAF values.

4.1.2 Earthworms

Concentrations of organic contaminants in earthworms are assumed to be a function of partitioning between soil water and the earthworm tissues (Connell and Markwell 1990, Sample et al. 1997b, Jager 1998):

$$C_{worm} = K_{BW} C_w$$

where,

C_{worm} = concentration in worm (mg/kg dry weight),

K_{BW} = biota/soil water partitioning coefficient,

and

C_w = concentration in soil water (mg/L).

K_{BW} was estimated by Connell and Markwell (1990) based on data for 32 lipophilic chemicals in earthworms:

$$\log K_{BW} = \log K_{ow} - 0.6$$

To reconstruct the variation in the data on which the linear regression model for K_{BW} is based, regression analyses were redone using the data presented in Connell and Markwell (1990), resulting in the following:

$$\log K_{BW} = 1.001 * [\log K_{ow}] - 0.553 + \varepsilon \quad (n=100, r^2=0.83)$$

where,

ε = regression error (normal distribution, mean=0, STD=σ),

σ = square root mean square error from the regression = 0.63566.

The conventional formula for estimation of the concentration of a chemical in water (C_w) based on concentrations in soil is:

$$C_w = C_s/K_d$$

where,

C_s = concentration in soil (mg/kg dry weight),

K_d = soil (or sediment)/water partitioning coefficient.

For non-ionic organic compounds, K_d may be estimated as:

$$K_d = f_{oc}K_{oc}$$

where,

f_{oc} = fraction of organic carbon in soil,

K_{oc} = water/ soil organic carbon partitioning coefficient.

Specific values of K_{oc} may not be available for all possible chemicals. Therefore, a family of models for estimation of K_{oc} from K_{ow} for different classes of chemicals was developed based on data presented in Gerstl (1990):

PCBs: $\log K_{oc} = 0.890*(\log K_{ow}) - 0.732 + \varepsilon$ (root MSE=0.56569, n=15, r^2=0.70)

Nonpolar PAHs: $\log K_{oc} = 0.890*(\log K_{ow}) + 0.279 + \varepsilon$ (root MSE=0.32984, n=14, r^2=0.90)

Aromatic Halogenated Hydrocarbons: $\log K_{oc} = 0.974*(\log K_{ow}) - 0.224 + \varepsilon$ (root MSE=0.34944, n=26, r^2=0.88)

Aromatic Non-halogenated Hydrocarbons: $\log K_{oc} = 0.529*(\log K_{ow}) + 0.918 + \varepsilon$ (root MSE=0.37489, n=37, r^2=0.66)

Chlorophenols: $\log K_{oc} = 1.076*(\log K_{ow}) - 0.801 + \varepsilon$ (root MSE=0.23701, n=8, r^2=0.91)

Triazines: $\log K_{oc} = 0.586*(\log K_{ow}) + 0.826 + \varepsilon$ (root MSE=0.18291, n=12, r^2=0.89)

The set of models outlined above for estimating K_{BW}, K_d, K_{oc}, and C_w were combined as follows to produce an overall model for estimation of BAFs for earthworms:

Original model: $C_{worm} = K_{BW} \times C_w$

Substitute C_s/K_d for C_w: $C_{worm} = K_{BW} \times C_s/K_d$

Multiply both sides of equation by $1/C_s$:

$$C_{worm}/C_s = K_{BW} / K_d$$

Because the BAF is the ratio between concentrations in biota and that in the media they reside in, C_{worm}/C_s = BAF, and the previous equation is equivalent to:

$$BAF = K_{BW} / K_d$$

Substitute for K_{BW} and K_d:

$$BAF = 10^{(\log Kow - 0.6)} / [f_{oc} \times 10^{(0.983 \log Kow + 0.00028)}]$$

To be conservative, f_{oc} for Screening-level calculations is set to 1 percent (0.01).

Distributions of earthworm BAFs for several organic contaminants were generated using the model outlined above in the EcoSSL report. For these, regression errors were all assumed to be normally distributed, and distributions for measured K_{oc} values were assigned triangular distributions (EPA, 2000).

4.1.3 Plants

Models to estimate chemical-specific soil-to-plant foliage BAFs based on K_{OW} have previously been developed and reported in Travis and Arms (1988). As part of the model verification process undertaken for the EcoSSLs, selected data used by Travis and Arms were chosen for verification. Because the data values could not be verified or were found to be erroneous, all literature cited in Travis and Arms (1988) was acquired, and with additional more recent data, a new model to estimate chemical-specific soil-to-plant foliage BAFs based on K_{OW} was developed (EPA, 2000). This new model is:

$$\log_{10}BAF=1.31-0.385(\log_{10}K_{OW})(n=463,\ p<0.0001,\ r^2=0.38).$$

4.1.4 Organics and Small Mammals

Similar to plants, models to estimate chemical-specific diet-to-mammal BAFs based on K_{OW} have previously been developed and reported in Travis and Arms (1988). Because most of these data values also could not be verified or were found to be erroneous, all literature cited in Travis and Arms (1988) was acquired, and with additional more recent data, a new model to estimate chemical-specific diet-to-mammal BAFs based on K_{OW} was developed (EPA, 2000). This new model is:

$$\log_{10}BAF=0.338-0.145(\log_{10}K_{OW})(n=55,\ p=0.38,\ r^2=0.015).$$

However, results of these EcoSSL analyses indicate that diet-to-mammal BAFs cannot be accurately estimated based on K_{ow} (EPA, 2000).

4.2 Newly Developed Bioaccumulation Values

Bioaccumulation data were needed for metals, explosives, chlorinated organics, PAHs, and uranium (Table 4-1). As described above, plant, earthworm, small mammal, benthic invertebrate, and aquatic organism uptake factors have been developed for multiple analytes, primarily metals (Tables 4-2 and 4-4). Additionally, there are standard bioaccumulation models for aquatic organisms, plants, and earthworms, which are based on the octonal-water partition coefficient of organic analytes (see Section 4.1). Newly developed data includes uptake factors for terrestrial invertebrates (excluding earthworms), as well as uptake factors for various plant parts (i.e., seeds, fruit, leaf, root, stem, and whole plant).

Database Development

Although data for bioaccumulation of metals in plants was available, this data is likely inappropriate for seeds and fruit, both of which are common wildlife foods. Likewise, earthworms may not represent other terrestrial insects that do not live in the soil. In fact, use of earthworm bioaccumulation factors likely will overestimate exposure to other terrestrial insects. To address these data gaps, we compiled information from a recent unpublished study that determined bioaccumulation factors for arthropods, and focused further data searches for bioaccumulation of metals in seeds, fruits, and terrestrial insects other than earthworms. PAH bioaccumulation data for plants and, to a lesser extent, earthworms, is also available (EPA, 2000); therefore our search for PAH data focused on terrestrial invertebrates, seeds, and fruits. Data for all food types were needed for explosives, chlorinated organics, and uranium.

4.2.1.1 Literature Search and Evaluation

A literature search was performed for studies that reported chemical concentrations in co located biota and media samples. Literature databases searched included those hosted by the Defense Technical Information Center (DTIC-STINET: Technical Reports), the U.S. EPA (ECOTOX Database Systems), and the National Library of Medicine (TOXLINE: Toxicology Literature Online). Over 250 references were collected and reviewed for relevant data (i.e., reported media and biota concentrations or diet and biota concentrations). Very few studies containing information necessary to calculate bioaccumulation in aquatic organisms, small mammals, and benthic invertebrates were located; therefore, databases were developed for terrestrial invertebrates and plants.

4.2.1.2 Data Selection and Database Parameters

Terrestrial invertebrate data were restricted to studies that reported whole-body concentrations. Plant data included studies that reported concentrations in seeds, fruits, stems, leaves, roots, and/or whole plant. To ensure relevancy of the soil-to-biota factors and models to field situations, only field studies in which resident terrestrial invertebrates were collected were considered. In general, most bioaccumulation models are based on field collected data; however, some laboratory studies were used if they were of sufficient duration to approximate field conditions. Therefore, all terrestrial invertebrate and plant material residues were assumed to be at equilibrium with soil concentrations.

To ensure comparability of data, only "total" chemical analyses of both soil and biota (e.g., resulting from extractions of metals using concentrated acids) were included. Data resulting from diethylenetriaminepentaacetic acid (DTPA), acetic acid, and other mild extraction methods were excluded. The mean (or composite) chemical concentration in media and biota reported for each sampling location evaluated in each study was considered an observation. If data for multiple species were reported at a site, each was considered a separate observation. Soil and biota data in the database were reported as mg/kg dry weight. If studies reported biota concentrations in wet weight, then dry weight concentrations were either calculated using the water content presented in the study or estimated assuming water content percentages as presented in Table 3-4 when water content was not presented in the study.

Data concerning species, soil pH, percent organic matter (OM), cation exchange capacity (CEC), soil texture, and soil Ca concentration (mg/kg dry wt) were included in the database whenever reported. Additionally, class, order, and family taxonomic data were included for each species in the database. This data was used to develop uptake factors by taxon for terrestrial invertebrates. Because chemical uptake was expected to vary according to terrestrial invertebrate diet preferences, each species was assigned to one of three trophic groups: predator (diet consisting primarily of other insects), herbivore (diet consisting primarily of plant material), and detritivore (diet consisting primarily of organic matter in the leaf litter).

Summaries of the analytical methods and data presented for each study included in the database are presented in Appendix A. The terrestrial invertebrate and plant bioaccumulation database are presented in Appendix B (Tables B-1 and B-2, respectively).

4.2.1.2 Quality Assurance/Quality Control for the Bioaccumulation Dataset

To ensure the accuracy of the database, all data was verified by at least one reviewer. The reviewer would first exam the study for data presented and analytical methods used. The reviewer would then check all calculations and conversions necessary to obtain required units (e.g., mg/kg dry weight). Finally, a minimum of 25 percent of all data was checked. If an error was found during this check, then 100 percent of the data was verified. Unit conversion and transposition errors were the most common types of errors found; however these were infrequent. All errors were corrected.

4.2.2 Summary of Results

Existing media-to-biota bioaccumulation models (empirically-based) were available for all inorganics in Table 4-1 except for cobalt for benthic invertebrates and aquatic organisms, selenium for benthic invertebrates, uranium for plants, small mammals, benthic invertebrates, and aquatic organisms, and vanadium for plants, benthic invertebrates, and aquatic organisms. Media-to-biota bioaccumulation models for dieldrin also were available for plants and small mammals, and DDT, DDD, and DDE models were available for plants, small mammals, and earthworms. PCB bioaccumulation models were available for earthworms and benthic invertebrates. Existing data for PAHs was only available for plants, whereas no empirically-based models have been developed explosives. Because few studies were found with data appropriate for calculating accumulation of relevant chemicals to aquatic organisms, earthworms, and small mammals, the simple uptake factors, empirically-based regression models, and K_{ow}-based models discussed in Section 4.1 were considered sufficient for use in ARAMS.

Of over 200 studies collected, 74 were identified that contained data suitable for inclusion in the developed databases. Thirty-seven studies were used in the terrestrial invertebrate database and 44 were used in the plant database. Bioaccumulation factors (BAFs) were developed for terrestrial invertebrates other than earthworms and for fruits, seeds, leaf, root, and whole plant.

Soil-to-terrestrial invertebrate BAFs for silver, aluminum, arsenic, barium, beryllium, calcium, cadmium, cobalt, chromium, copper, fluoride, iron, mercury, potassium, magnesium, manganese, sodium, nickel, lead, antimony, selenium, thallium, vanadium, and zinc were developed (Table 4-5). No data were available for explosives and relevant organics. As data supported, BAFs were developed by class and order as indicated in Table 4-5. In general, median BAFs were <1; however, there were some notable exceptions. BAFs >1 were observed for bioaccumlation of cadmium in 3 classes of invertebrates including Arachnida (both families represented), Diplopoda, and Insecta (dipterans only). Copper also had BAFs >1 in these 3 classes (only one family in Arachnida had a BAF>1), as well as in Isopoda and Mollusca (represented by slugs). A BAF >1 was overserved for arsenic bioaccumulation in order Diplopoda; however, this value is highly uncertain because only one observation was available. Members of family Araneae (order Arachnida) had a mercury BAF >1, and lepidopterans (order Insecta) had a magnesium BAF >1. Zinc was found to bioaccumulate at values >1 in orders Diplopoda and Mollusca (represented by slugs). BAFs for potassium and sodium were >1 for all orders and families with sufficient data for evaluation; however, this was expected because these are essential nutrients. Finally, selenium BAFs in arachnids (family Arneae) and in 2 families of insects (Lepidoptera and Orthoptera, but not in family Coleoptera) were >1.

Development of BAFs for fruits, seeds, leaf, root, and whole plant was possible for many inorganics (e.g., cadmium, copper, nickel, lead, selenium, and zinc); however, it was only possible to develop soil-to-root and soil-to-leaf BAFs for explosives (e.g., 2-ANT, RDX, and TNT) and PAHs (e.g., anthracene, naphthalene, and benzo(a)pyrene) (Table 4-6). Insufficient data were available to develop BAFs for the other relevant organics. As with terrestrial invertebrates, most BAFs developed were <1. Roots had BAFs >1 for boron, molybdenum, selenium, and uranium. Bioaccumulation of boron, molybdenum, and selenium in leaf tissue also was >1. In contrast, fruits had BAFs <1 for all 7 inorganics evaluated including selenium and uranium (Table 4-6). Bioaccumulation was low in seeds, with 6 of the inorganics evaluated having BAFs <1 and 15 having BAFs equal to 1. Although data was available for bioaccumulation of 4 explosives and 17 PAHs to roots, none of these analytes had BAFs >1. However, BAFs >1 for 2 explosives (2-ADNT and 4-ADNT) and 5 PAHs (ace/fluorene, fluoranthene, naphthlene, phenanthrene, and pyrene) were observed in leaf tissue. The BAF for anthracene (a PAH) in leaf tissue was equal to 1.

As indicated in Section 4.1, the uncertainty associated with BAFs can be high. Therefore, regression analysis and validation of these data are necessary to reduce uncertainty. Additionally, 22 studies that reported concentrations in media and wildlife food items of interest were located; however, the analyte concentrations in media, biota, or both were presented in graphic form. These data are likely to be useful if raw data could be obtained from the authors of the studies.

Table 4-5
Summary Statistics for Soil-Arthopod BAFs Derived from Published Field Data

Analyte	Class	Order	n	mean	std	ucl95	min	median	p90	max
Ag	Arachnida	Araneae	5	0.42246	0.38704	0.7081	0.05362	0.35833	1	1
Ag	Insecta		22	0.04038	0.04295	0.0555	0.0037	0.025	0.12	0.1695
Ag	Insecta	Coleoptera	5	0.02486	0.02158	0.0408	0.0069	0.025	0.06	0.06
Ag	Insecta	Lepidoptera	6	0.05459	0.07165	0.1029	0.0037	0.01242	0.1695	0.1695
Ag	Insecta	Orthoptera	11	0.03969	0.02966	0.0544	0.01429	0.0339	0.05	0.12
Al	Arachnida	Araneae	6	0.0038	0.00353	0.0062	0.00114	0.00186	0.0084	0.0084
Al	Insecta		24	0.00499	0.00696	0.0073	0.00075	0.00266	0.0111	0.0271
Al	Insecta	Coleopterara	5	0.00806	0.00989	0.0154	0.00257	0.00298	0.0255	0.0255
Al	Insecta	Lepidoptera	7	0.00706	0.00896	0.0126	0.00228	0.00354	0.0271	0.0271
Al	Insecta	Orthoptera	12	0.0025	0.00286	0.0039	0.00075	0.00172	0.0041	0.0111
As	Arachnida	Araneae	14	0.13871	0.09241	0.1795	0.02404	0.11865	0.2781	0.3541
As	Diplopoda		1	1.03571	.	.	1.03571	1.03571	1.0357	1.0357
As	Insecta		44	0.07074	0.05927	0.0855	0.01289	0.06146	0.1258	0.3448
As	Insecta	Coleoptera	14	0.09172	0.0422	0.1103	0.01289	0.10264	0.1368	0.1588
As	Insecta	Lepidoptera	7	0.09508	0.11326	0.1657	0.01289	0.06329	0.3448	0.3448
As	Insecta	Orthoptera	23	0.05056	0.03771	0.0635	0.01289	0.03517	0.0877	0.1724
As	Mollusca	slug	1	0.31429	.	.	0.31429	0.31429	0.3143	0.3143
Ba	Arachnida	Araneae	6	0.03219	0.01888	0.0449	0.01563	0.02678	0.0672	0.0672
Ba	Insecta		27	0.06102	0.06475	0.0816	0.01258	0.03511	0.1536	0.3024
Ba	Insecta	Coleoptera	5	0.08203	0.0579	0.1248	0.01258	0.09878	0.1557	0.1557
Ba	Insecta	Lepidoptera	7	0.10423	0.09339	0.1625	0.03063	0.06037	0.3024	0.3024
Ba	Insecta	Orthoptera	14	0.02529	0.01095	0.0301	0.01306	0.02162	0.0399	0.0519
Be	Arachnida	Araneae	6	0.02249	0.00721	0.0274	0.01429	0.02105	0.0333	0.0333
Be	Insecta		24	0.02764	0.03045	0.0379	0.01429	0.01886	0.0286	0.1429
Be	Insecta	Coleoptera	5	0.01634	0.00281	0.0184	0.01429	0.01538	0.0211	0.0211
Be	Insecta	Lepidoptera	7	0.0487	0.05268	0.0816	0.01538	0.02105	0.1429	0.1429
Be	Insecta	Orthoptera	12	0.02006	0.00439	0.0222	0.01429	0.02105	0.0238	0.0286
Ca	Arachnida	Araneae	6	0.60309	0.52726	0.9583	0.04713	0.53264	1.497	1.497
Ca	Insecta		24	0.47401	0.33705	0.5875	0.02644	0.41719	0.8584	1.424
Ca	Insecta	Coleoptera	5	0.38325	0.24962	0.5674	0.08923	0.39838	0.6481	0.6481
Ca	Insecta	Lepidoptera	7	0.6862	0.45809	0.9719	0.04955	0.6326	1.424	1.424
Ca	Insecta	Orthoptera	12	0.38804	0.24484	0.5047	0.02644	0.37003	0.6766	0.8584
Cd	Arachnida		57	5.2253	7.74869	6.9188	0.12321	2.35026	15.15	37.2727
Cd	Arachnida	Araneae	48	4.39536	7.42414	6.1635	0.12321	1.83917	14.8	37.2727
Cd	Arachnida	Opilioneae	9	9.65165	8.38475	14.2633	2.08784	8.25	27.35	27.35
Cd	Chilopoda		5	0.90693	1.31383	1.8764	0.05847	0.33906	3.2	3.2
Cd	Diplopoda		10	0.992	0.406	1.205	0.47429	1.0577	1.574	1.67
Cd	Insecta		210	2.604	8.305	3.55	0.02057	0.472	4.078	92.73
Cd	Insecta	Coleoptera	67	2.077	5.339	3.153	0.02222	0.6027	3.69	37.06
Cd	Insecta	Collembola	6	0.235	0.204	0.373	0.02109	0.2222	0.558	0.56
Cd	Insecta	Diptera	3	1.479	0.785	2.226	0.82857	1.2571	2.35	2.35
Cd	Insecta	Hemiptera	2	2.43	0.962	3.552	1.75	2.43	3.11	3.11
Cd	Insecta	Homoptera	1	0.12	.	.	0.12	0.12	0.12	0.12
Cd	Insecta	Hymenoptera	23	4.631	7.185	7.103	0.03818	0.8716	18.5	22.75
Cd	Insecta	Lepidoptera	24	0.55	0.678	0.778	0.02057	0.2518	1.704	2.68
Cd	Insecta	Neuroptera	1	1.72	.	.	1.72	1.72	1.72	1.72
Cd	Insecta	Orthoptera	26	0.983	2.151	1.679	0.04028	0.1918	1.633	10.5
Cd	Isopoda		5	2.31	2.796	4.372	0.19854	1.8543	7.08	7.08
Co	Arachnida	Araneae	6	0.012	0.013	0.021	0.00435	0.007	0.038	0.04
Co	Insecta		24	0.01	0.009	0.013	0.00268	0.0059	0.023	0.03
Co	Insecta	Coleoptera	5	0.011	0.013	0.021	0.00268	0.0057	0.034	0.03
Co	Insecta	Lepidoptera	7	0.012	0.01	0.018	0.00394	0.0073	0.031	0.03
Co	Insecta	Orthoptera	12	0.008	0.007	0.011	0.00326	0.0053	0.02	0.02
Cr	Arachnida	Araneae	6	0.195	0.183	0.318	0.04534	0.1177	0.44	0.44
Cr	Diplopoda		1	0.015	.	.	0.01545	0.0155	0.015	0.02
Cr	Insecta		28	0.144	0.197	0.206	0.01	0.0651	0.546	0.74
Cr	Insecta	Coleoptera	9	0.137	0.179	0.235	0.01	0.0846	0.6	0.6
Cr	Insecta	Lepidoptera	7	0.304	0.291	0.486	0.03963	0.1548	0.741	0.74
Cr	Insecta	Orthoptera	12	0.057	0.034	0.074	0.01984	0.0506	0.088	0.14
Cr	Mollusca	slug	1	0.259	.	.	0.25909	0.2591	0.259	0.26
Cu	Arachnida		57	21.039	60.203	34.196	0.02827	1.385	56.897	383.68
Cu	Arachnida	Araneae	48	24.784	65.019	40.268	0.02827	1.4413	91.503	383.68
Cu	Arachnida	Opilioneae	9	1.067	0.906	1.565	0.21459	0.6762	2.963	2.96
Cu	Chilopoda		5	1.265	1.721	2.535	0.02189	0.2907	4.141	4.14

Table 4-5

Summary Statistics for Soil-Arthopod BAFs Derived from Published Field Data

Analyte	Class	Order	n	mean	std	ucl95	min	median	p90	max
Cu	Diplopoda		11	5.184	3.169	6.76	1.26043	5.2767	8.889	8.89
Cu	Insecta		170	37.627	232.676	67.072	0.00495	0.623	50.282	2897
Cu	Insecta	Coleoptera	56	0.512	0.631	0.651	0.00495	0.2873	1.561	2.44
Cu	Insecta	Diptera	2	1.818	0	1.818	1.81818	1.8182	1.818	1.82
Cu	Insecta	Hymenoptera	18	0.36	0.513	0.56	0.01129	0.1895	1.106	2.11
Cu	Insecta	Lepidoptera	21	0.684	0.473	0.854	0.08602	0.6667	1.491	1.52
Cu	Insecta	Orthoptera	25	116.885	579.192	308.019	0.07183	0.4867	4.912	2897
Cu	Isopoda		19	5.2263	4.8764	7.0722	0.043	3.5112	12.9524	14.3846
Cu	Mollusca	slug	1	1.3846	.	.	1.3846	1.3846	1.3846	1.3846
F	Insecta	Diptera	2	0.1239	0.1589	0.3093	0.0116	0.1239	0.2363	0.2363
Fe	Arachnida	Araneae	6	0.0285	0.0365	0.0531	0.0064	0.0151	0.1024	0.1024
Fe	Insecta		24	0.0096	0.0114	0.0134	0.0016	0.0048	0.027	0.0458
Fe	Insecta	Coleoptera	5	0.0069	0.0038	0.0097	0.0036	0.0064	0.0133	0.0133
Fe	Insecta	Lepidoptera	7	0.0178	0.017	0.0284	0.0041	0.0072	0.0458	0.0458
Fe	Insecta	Orthoptera	12	0.0059	0.0069	0.0092	0.0016	0.0043	0.0078	0.027
Hg	Arachnida	Araneae	6	1.9656	2.3915	3.5765	0.3158	1.0444	6.6667	6.6667
Hg	Insecta		24	0.9859	1.326	1.4325	0.0581	0.625	2	6.6667
Hg	Insecta	Coleoptera	5	0.8339	0.7321	1.3741	0.0581	0.5556	2	2
Hg	Insecta	Lepidoptera	7	1.5257	2.2893	2.9534	0.0581	0.8333	6.6667	6.6667
Hg	Insecta	Orthoptera	12	0.7343	0.5982	1.0193	0.0581	0.5903	1.6	2
K	Arachnida	Araneae	6	5.4434	1.6866	6.5795	3.6184	4.8634	7.7083	7.7083
K	Insecta		24	7.1962	3.6147	8.4136	3.45	6.2162	12.9861	15.2143
K	Insecta	Coleoptera	5	4.4763	0.6956	4.9896	3.45	4.3441	5.1515	5.1515
K	Insecta	Lepidoptera	7	12.0576	2.5936	13.675	7.6316	11.7672	15.2143	15.2143
K	Insecta	Orthoptera	12	5.4937	1.3824	6.1522	3.4539	5.4459	6.9291	7.6596
Mg	Arachnida	Araneae	6	0.9267	0.31	1.1356	0.6211	0.9183	1.4621	1.4621
Mg	Insecta		26	0.7662	0.407	0.8979	0.2845	0.6911	1.5047	1.7517
Mg	Insecta	Coleoptera	5	0.6858	0.1665	0.8087	0.4105	0.6957	0.8208	0.8208
Mg	Insecta	Lepidoptera	7	1.2788	0.4121	1.5357	0.5588	1.4953	1.7517	1.7517
Mg	Insecta	Orthoptera	14	0.5386	0.1785	0.6173	0.2845	0.5107	0.7985	0.8358
Mn	Arachnida	Araneae	6	0.0929	0.0976	0.1586	0.0279	0.0436	0.2773	0.2773
Mn	Insecta		26	0.1225	0.1937	0.1851	0.0093	0.0588	0.2267	0.8617
Mn	Insecta	Coleoptera	5	0.0901	0.0476	0.1252	0.0465	0.063	0.1495	0.1495
Mn	Insecta	Lepidoptera	7	0.0767	0.0674	0.1187	0.0311	0.0568	0.2267	0.2267
Mn	Insecta	Orthoptera	14	0.157	0.2579	0.2707	0.0093	0.0578	0.638	0.8617
Na	Arachnida	Araneae	6	42.9695	20.5893	56.8387	25.7432	34.0381	79.803	79.803
Na	Insecta		24	10.3541	8.3258	13.1583	0.7696	8.9187	23.3266	26.4793
Na	Insecta	Coleoptera	5	16.243	9.9133	23.558	4.0506	17.4556	26.4793	26.4793
Na	Insecta	Lepidoptera	7	3.0914	3.5091	5.2798	0.7696	1.4821	10.8114	10.8114
Na	Insecta	Orthoptera	12	12.1371	7.049	15.4946	2.6329	12.529	21.7039	23.3266
Ni	Arachnida	Araneae	6	0.1607	0.1237	0.244	0.0549	0.1234	0.404	0.404
Ni	Diplopoda		1	0.0193	.	.	0.0193	0.0193	0.0193	0.0193
Ni	Insecta		28	0.1765	0.2035	0.24	0.0549	0.1044	0.5118	1.0101
Ni	Insecta	Coleoptera	9	0.1689	0.137	0.2444	0.07168	0.1167	0.512	0.512
Ni	Insecta	Lepidoptera	7	0.2841	0.369	0.5142	0.05495	0.099	1.01	1.01
Ni	Insecta	Orthoptera	12	0.1195	0.052	0.1443	0.05495	0.1094	0.196	0.202
Ni	Mollusca	slug	1	0.3133	.	.	0.31333	0.3133	0.313	0.313
Pb	Arachnida		59	9.5616	24.481	14.8204	0.00185	0.0692	32.399	115.961
Pb	Arachnida	Araneae	50	11.2675	26.267	17.3967	0.00185	0.0411	44.637	115.961
Pb	Arachnida	Opilioneae	9	0.0843	0.044	0.1085	0.0521	0.0715	0.197	0.197
Pb	Chilopoda		5	0.0161	0.011	0.0241	0.00031	0.0161	0.029	0.029
Pb	Diplopoda		10	0.0924	0.054	0.1206	0.0299	0.0734	0.166	0.18
Pb	Insecta		179	23.8301	71.894	32.6966	0	0.0621	64.266	553.901
Pb	Insecta	Coleoptera	44	0.0289	0.039	0.0387	0.00067	0.0154	0.075	0.221
Pb	Insecta	Diptera	4	0.3312	0.193	0.4907	0.13864	0.3004	0.585	0.585
Pb	Insecta	Hymenoptera	18	0.0378	0.044	0.0549	0.00239	0.0178	0.114	0.176
Pb	Insecta	Lepidoptera	21	0.0476	0.062	0.0698	0.00149	0.0133	0.142	0.212
Pb	Insecta	Orthoptera	22	0.0271	0.038	0.0403	0.00067	0.0051	0.064	0.151
Pb	Isopoda		5	0.2015	0.197	0.3467	0.00132	0.2566	0.456	0.456
Pb	Mollusca	slug	1	0.1413	.	.	0.1413	0.1413	0.141	0.141
Sb	Arachnida	Araneae	2	0.0074	0	0.0076	0.00732	0.0074	0.008	0.008
Sb	Insecta		6	0.0094	0.008	0.0146	0.00455	0.0073	0.025	0.025
Sb	Insecta	Lepidoptera	2	0.0162	0.013	0.0307	0.00732	0.0162	0.025	0.025
Sb	Insecta	Orthoptera	4	0.006	0.002	0.0073	0.00455	0.0059	0.008	0.008

Table 4-5
Summary Statistics for Soil-Arthopod BAFs Derived from Published Field Data

Analyte	Class	Order	n	mean	std	ucl95	min	median	p90	max
Se	Arachnida	Araneae	3	3.4501	2.506	5.8373	1.06383	3.2258	6.061	6.061
Se	Insecta		19	1.7055	1.373	2.2252	0.01833	1.6129	4.149	4.255
Se	Insecta	Coleoptera	3	0.5611	0.911	1.429	0.01833	0.0521	1.613	1.613
Se	Insecta	Lepidoptera	5	2.1931	1.502	3.3011	0.3125	1.7544	4.255	4.255
Se	Insecta	Orthoptera	11	1.796	1.343	2.4642	0.10417	1.6129	3.774	4.149
Tl	Arachnida	Araneae	5	0.0657	0.026	0.0846	0.05128	0.0526	0.111	0.111
Tl	Insecta		18	0.0775	0.066	0.1034	0.05128	0.0541	0.256	0.263
Tl	Insecta	Coleoptera	4	0.0554	0.004	0.0585	0.05263	0.0541	0.061	0.061
Tl	Insecta	Lepidoptera	5	0.138	0.111	0.2201	0.05405	0.0606	0.263	0.263
Tl	Insecta	Orthoptera	9	0.0539	0.003	0.0554	0.05128	0.0526	0.061	0.061
V	Arachnida	Araneae	6	0.0082	0.004	0.011	0.00403	0.0081	0.015	0.015
V	Insecta		25	0.01	0.008	0.0127	0.00345	0.0066	0.02	0.036
V	Insecta	Coleoptera	5	0.0084	0.006	0.0128	0.00345	0.0065	0.018	0.018
V	Insecta	Lepidoptera	7	0.0145	0.011	0.0214	0.00345	0.0119	0.036	0.036
V	Insecta	Orthoptera	13	0.0082	0.007	0.011	0.00345	0.0066	0.016	0.028
Zn	Arachnida		59	31.4026	94.064	51.609	0.09733	0.7724	106.513	633.929
Zn	Arachnida	Araneae	50	36.8854	101.351	60.535	0.09733	0.8555	138.128	633.929
Zn	Arachnida	Opilioneae	9	0.9425	0.642	1.296	0.34115	0.6907	2.289	2.289
Zn	Chilopoda		5	0.5353	0.604	0.981	0.10425	0.4069	1.578	1.578
Zn	Diplopoda		11	1.6848	1.402	2.382	0.16928	1.3913	3.867	4.261
Zn	Insecta		178	27.5521	72.056	36.464	0.0103	0.688	93.469	662.5
Zn	Insecta	Coleoptera	49	0.5444	0.718	0.714	0.0103	0.2643	1.514	3.349
Zn	Insecta	Collembola	6	0.2723	0.387	0.533	0.02303	0.1073	1.04	1.04
Zn	Insecta	Diptera	4	1.0138	1.461	2.219	0.15862	0.3489	3.199	3.199
Zn	Insecta	Hymenoptera	18	0.6726	1.205	1.141	0.03162	0.1741	3.313	4.419
Zn	Insecta	Lepidoptera	21	0.4821	0.467	0.65	0.08271	0.1906	1.304	1.487
Zn	Insecta	Orthoptera	26	0.7359	0.919	1.033	0.03529	0.3406	2.369	3.52
Zn	Isopoda		5	0.7952	1.039	1.562	0.1205	0.418	2.606	2.606
Zn	Mollusca	slug	1	2.7083	.	.	2.70833	2.7083	2.708	2.708

Table 4-6

Summary Statistics for Soil-Plant Tissue BAFs Derived from Published Field Data

Analyte	Type	tissue	n	mean	std	ucl95	min	median	p90	max
Cd	Inorganic	fruit	2	0.128	0.133	0.283	0.0343	0.1283	0.22	0.22
Cu	Inorganic	fruit	20	0.115	0.174	0.18	0.0161	0.0453	0.44	0.63
Ni	Inorganic	fruit	14	0.029	0.03	0.04	0.00289	0.02444	0.06	0.09
Pb	Inorganic	fruit	2	0.058	0.06	0.12	0.018	0.05778	0.0976	0.1
Se	Inorganic	fruit	16	0.109	0.07	0.14	0.02162	0.08888	0.2067	0.31
U	Inorganic	fruit	4	0.002	0	0	0.00005	0.00153	0.0029	0
Zn	Inorganic	fruit	2	0.069	0.069	0.149	0.02034	0.06887	0.117	0.12
Ag	Inorganic	seed	11	0.11	0.296	0.257	0.0058	0.0133	0.05	1
Al	Inorganic	seed	27	0.557	0.504	0.717	0.0016	1	1	1
Ba	Inorganic	seed	28	0.627	0.424	0.76	0.0132	1	1	1
Ca	Inorganic	seed	28	1.696	2.167	2.372	0.0414	1	4.67	10.61
Cd	Inorganic	seed	43	1.268	2.154	1.81	0.0029	1	1.98	12
Co	Inorganic	seed	29	0.532	0.495	0.683	0.003	1	1	1
Cr	Inorganic	seed	29	0.559	0.468	0.702	0.0265	1	1	1
Cu	Inorganic	seed	32	0.569	0.427	0.694	0.013	0.5364	1	1
Fe	Inorganic	seed	27	0.559	0.5	0.72	0.00333	1	1	1
Hg	Inorganic	seed	1	0.474	.	.	0.47368	0.47368	0.4737	0.47
K	Inorganic	seed	27	4.118	5.77	5.95	0.87568	1	12.8369	23.84
Mg	Inorganic	seed	27	1.237	0.75	1.47	0.47086	1	2.414	3.46
Mn	Inorganic	seed	27	0.587	0.47	0.74	0.02457	1	1	1
Na	Inorganic	seed	16	0.774	0.42	0.95	0.18561	1	1.1892	1.64
Ni	Inorganic	seed	29	0.594	0.44	0.73	0.01923	1	1	1
Pb	Inorganic	seed	31	0.51	0.48	0.65	0.00018	0.19547	1	1
Sb	Inorganic	seed	1	0.009	.	.	0.00909	0.00909	0.0091	0.01
Se	Inorganic	seed	3	0.992	0.01	1.01	0.975	1	1	1
U	Inorganic	seed	12	0.004	0.004	0.006	0.00006	0.00104	0.01	0.01
V	Inorganic	seed	27	0.559	0.503	0.718	0.00145	1	1	1
Zn	Inorganic	seed	31	0.632	0.413	0.755	0.00458	1	1	1.08
2-ADNT	Explosive	root	9	5.693	13.284	12.999	0.0001	0.0007	39.6	39.6
4-ADNT	Explosive	root	10	6.661	21.06	17.65	0.0001	0.0008	33.3	66.6
RDX	Explosive	root	12	24.123	75.37	60.02	0.00209	0.14225	15.8319	263
TNT	Explosive	root	9	0.748	1.51	1.58	0.00002	0.001	4.5	4.5
As	Inorganic	root	5	1.125	0.573	1.548	0.5	1.125	2	2
B	Inorganic	root	8	1.537	0.955	2.094	0.3316	1.4413	2.92	2.92
Cd	Inorganic	root	7	1.121	1.258	1.906	0.0407	0.4444	3	3
Cu	Inorganic	root	6	0.168	0.11	0.242	0.0265	0.2136	0.28	0.28
Mn	Inorganic	root	3	0.072	0.05	0.12	0.03466	0.05275	0.1286	0.13
Mo	Inorganic	root	8	10.359	18.29	21.03	0.11111	1.70253	51.3924	51.39
Se	Inorganic	root	9	4.189	6.38	7.7	0.18333	1.0439	15.5122	15.51
U	Inorganic	root	7	2.77	2.31	4.21	0.00008	2.91667	5.283	5.28
V	Inorganic	root	5	0.515	0.322	0.753	0.28481	0.40506	1.082	1.08
Zn	Inorganic	root	4	0.489	0.082	0.557	0.43478	0.45652	0.609	0.61
Ace/Fluorene	PAH	root	3	0.531	0.472	0.981	0.0946	0.4682	1.03	1.03
Anthracene	PAH	root	6	3.736	5.395	7.37	0.0049	0.7248	12.5	12.5
Benz/Chrysene	PAH	root	3	0.024	0.023	0.046	0.0096	0.0104	0.05	0.05
Benzo(a)pyrene	PAH	root	4	0.091	0.091	0.166	0.0118	0.0655	0.22	0.22
Benzo(b)fluoranthene	PAH	root	2	0.058	0.059	0.127	0.0166	0.0583	0.1	0.1
benzo(e)pyrene	PAH	root	1	0.153	.	.	0.15254	0.15254	0.153	0.15
Benzo(ghi)perylene	PAH	root	3	0.043	0.036	0.077	0.0084	0.0393	0.08	0.08
Benzo(k)fluoranthene	PAH	root	1	0.1	.	.	0.1	0.1	0.1	0.1
chrysene	PAH	root	1	0.13	.	.	0.12973	0.12973	0.13	0.13
Coronene	PAH	root	2	0.102	0.037	0.145	0.0756	0.1018	0.13	0.13
Dibenz(ah)anthracene	PAH	root	1	0.233	.	.	0.23256	0.23256	0.2326	0.23
Fluoranthene	PAH	root	4	0.392	0.74	1.01	0.01093	0.02562	1.5068	1.51
fluorene	PAH	root	1	0.037	.	.	0.03663	0.03663	0.037	0.04
Indeno(123cd)pyrene	PAH	root	1	0.133	.	.	0.13333	0.13333	0.1333	0.13
Naphthlene	PAH	root	4	0.748	0.45	1.12	0.24529	0.75506	1.2353	1.24
Phenanthrene	PAH	root	4	0.881	1.51	2.13	0.02254	0.18043	3.1395	3.14
Pyrene	PAH	root	4	0.295	0.47	0.68	0.02254	0.07862	1	1
Cu	Inorganic	Stem	2	0.067	0.066	0.145	0.0205	0.0674	0.11	0.11
Se	Inorganic	Stem	1	0.214	.	.	0.21429	0.21429	0.2143	0.21
U	Inorganic	Stem	3	0.008	0.01	0.01	0.00198	0.00685	0.0154	0.02
2-ADNT	Explosive	leaf	1	9	.	.	9	9	9	9
4-ADNT	Explosive	leaf	1	21.4	.	.	21.4	21.4	21.4	21.4
RDX	Explosive	leaf	18	2.493	5.15	4.5	0.01439	0.42961	10.75	20.48

Table 4-6

Summary Statistics for Soil-Plant Tissue BAFs Derived from Published Field Data

Analyte	Type	tissue	n	mean	std	ucl95	min	median	p90	max
TNT	Explosive	leaf	2	0.159	0.23	0.42	0.00007	0.15945	0.3188	0.32
As	Inorganic	leaf	14	0.211	0.233	0.313	0.0126	0.0791	0.63	0.63
B	Inorganic	leaf	9	6.924	6.001	10.224	1.6837	5.7143	18.11	18.11
Ba	Inorganic	leaf	8	171.633	485.072	454.606	0.0387	0.1027	1372.13	1372.13
Cd	Inorganic	leaf	17	0.841	1.151	1.302	0.1105	0.3538	3.43	3.78
Co	Inorganic	leaf	2	0.538	0.02	0.562	0.5238	0.5382	0.55	0.55
Cr	Inorganic	leaf	2	0.105	0.02	0.129	0.0906	0.105	0.12	0.12
Cu	Inorganic	leaf	64	6.991	50.711	17.451	0.0038	0.2745	1.31	406
Hg	Inorganic	leaf	6	0.742	0.28	0.93	0.45	0.75	1	1
Mg	Inorganic	leaf	8	7.333	19.01	18.42	0.24664	0.56781	54.373	54.37
Mn	Inorganic	leaf	12	652.445	2255.04	1726.55	0.05576	0.32484	10.2217	7813.14
Mo	Inorganic	leaf	10	1.752	1.81	2.69	0.08261	1.25035	4.4177	5.56
Ni	Inorganic	leaf	3	0.509	0.32	0.81	0.13905	0.66667	0.72	0.72
Pb	Inorganic	leaf	21	0.117	0.21	0.19	0.00011	0.05129	0.2034	0.82
Sb	Inorganic	leaf	17	0.053	0.06	0.08	0.00343	0.03729	0.1487	0.22
Se	Inorganic	leaf	51	58.945	406.52	152.87	0.08542	0.58049	1.9677	2904.88
U	Inorganic	leaf	16	0.03	0.035	0.044	0.00088	0.0201	0.067	0.13
V	Inorganic	leaf	9	111.055	332.979	294.194	0.00633	0.05063	999	999
Zn	Inorganic	leaf	32	49.986	280.017	131.662	0.04583	0.33513	1.336	1584.5
Ace/Fluorene	PAH	leaf	3	2.884	3.016	5.757	0.5301	1.8369	6.28	6.28
Anthracene	PAH	leaf	8	1.36	1.011	1.949	0.1629	1	3.1	3.1
Benz/Chrysene	PAH	leaf	3	0.309	0.404	0.693	0.0284	0.1265	0.77	0.77
benzo(a)anthracene	PAH	leaf	1	0.537	.	.	0.53704	0.53704	0.537	0.54
Benzo(a)pyrene	PAH	leaf	7	0.087	0.06	0.124	0.0196	0.0656	0.2	0.2
Benzo(b)fluoranthene	PAH	leaf	6	0.227	0.19	0.355	0.0163	0.1728	0.48	0.48
benzo(e)pyrene	PAH	leaf	4	0.188	0.074	0.249	0.10169	0.18983	0.271	0.27
Benzo(ghi)perylene	PAH	leaf	7	0.296	0.453	0.578	0.0528	0.1306	1.31	1.31
Benzo(k)fluoranthene	PAH	leaf	4	0.238	0.135	0.349	0.08	0.255	0.36	0.36
chrysene	PAH	leaf	4	0.696	0.438	1.057	0.16216	0.78378	1.054	1.05
Coronene	PAH	leaf	3	1.926	2.325	4.141	0.5787	0.588	4.61	4.61
Dibenz(ah)anthracene	PAH	leaf	4	0.14	0.068	0.196	0.0698	0.1279	0.23	0.23
Fluoranthene	PAH	leaf	7	2.489	2.21	3.86	0.26838	2.46575	6.0274	6.03
fluorene	PAH	leaf	4	0.038	0.023	0.057	0.01089	0.04109	0.057	0.06
Indeno(123cd)pyrene	PAH	leaf	2	0.11	0.05	0.17	0.07143	0.10952	0.1476	0.15
Naphthlene	PAH	leaf	7	1.581	1.37	2.44	0.29412	1.05882	4.1937	4.19
Phenanthrene	PAH	leaf	7	4.096	2.62	5.73	0.69243	3.83721	7.9235	7.92
Pyrene	PAH	leaf	7	1.79	1.31	2.61	0.19324	1.85185	3.7037	3.7
Cd	Inorganic	wholeplant	24	0.586	0.948	0.905	0.0289	0.1641	1.74	3.39
Cu	Inorganic	wholeplant	19	0.291	0.243	0.383	0.0747	0.2238	0.87	0.93
Fl	Inorganic	wholeplant	2	1.82	2.5	4.73	0.05544	1.81971	3.584	3.58
Pb	Inorganic	wholeplant	16	0.016	0.01	0.02	0.0036	0.01433	0.0316	0.03
Zn	Inorganic	wholeplant	22	0.322	0.317	0.434	0.04584	0.20212	0.909	1.06

SECTION 5

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U.S. Army Center for Health Promotion and Preventive Medicine

Appendices

Development of Terrestrial Exposure and Bioaccumulation Information for the Army Risk Assessment Modeling System (ARAMS)

USACHPPM

CONSERVARE SALUTEM

APRIL 2004

Prepared for
Contract No. DAAD050-00-P-8365

U.S. Army Center for Health Promotion and Preventive Medicine

Toxicology Directorate

Health Effects Research Program

5158 Blackhawk Road
Aberdeen Proving Ground, MD 21010

Readiness Thru Health

Report

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Submitted to

Health Effects Research Program

April 2004

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APPENDIX A

Summary of Studies Included in the Terrestrial Invertebrate and Plant Bioaccumulation Databases

APPENDIX A

Summaries of Studies Included in the Bioaccumulation Databases

Reference: Andrew et al., 1989a
Analytes Considered: Pb
Species: plants, small mammals, invertebrates
Geographic Location of Study: Great Britain
Exposure Duration: field
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: soil and vegetation
Analytical Method: atomic absorption spectrophotometry
Extraction Method: Nitric acid wet oxidation
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: not reported
Purpose of Study: To examine distribution and accumulation of lead in a grassland ecosystem established on a revegetated tailings dam
Notes:

Reference: Andrew et al., 1989b
Analytes Considered: Zn
Species: plants, small mammals, invertebrates
Geographic Location of Study: Great Britain
Exposure Duration: field
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: soil and vegetation
Analytical Method: atomic absorption spectrophotometry
Extraction Method: Nitric acid wet oxidation
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: not reported
Purpose of Study: To examine distribution and accumulation of lead in a grassland ecosystem established on a revegetated tailings dam
Notes:

Reference: Andrew et al., 1989c
Analytes Considered: Fl
Species: plants, small mammals, invertebrates
Geographic Location of Study: Great Britain
Exposure Duration: field
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: soil
Analytical Method: fluoride ion-selective electrode
Extraction Method: Nitric acid
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: not reported

Purpose of Study: To determine the distribution of contaminants in a contaminated ecosystem
Notes:

Reference: Banuelos and Ajwa, 1999
Analytes Considered: As, B, Cd, Cr, Cu, Hg, Ni, Pb, Se, U, Zn
Species: Plants
Geographic Location of Study: Fresno, California, USA
Exposure Duration: field
Type of Tissue Analyzed: Roots and Shoots
Type of Source Media Analyzed: Soil
Analytical Method: AAS
Extraction Method: nitric acid (samples) hydrochloric:nitric acid (soil)
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: Review the soil and plant processes governing chemical form and the uptake and behavior of trace elements within plants.
Notes: Review and data summary form previous studies by the authors.

Reference: Banuelos et al., 1993
Analytes Considered: B, Se
Species: Plants
Geographic Location of Study: Los Banos, California, USA
Exposure Duration: field
Type of Tissue Analyzed: Roots and Shoots
Type of Source Media Analyzed: Soil
Analytical Method: AAS
Extraction Method: nitric acid
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: To determine the tolerance of selected plants to concentrations of B and Se in field soils
Notes:

Reference: Baroni et al., 2000
Analytes Considered: Antimony
Species: *Achillea ageratum, Plantago lancelolata, Silene vulgaris*
Geographic Location of Study: Italy
Exposure Duration: field
Type of Tissue Analyzed: Roots and Shoots
Type of Source Media Analyzed: Soil
Analytical Method: AAS
Extraction Method: Nitric Acid
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: Examine the accumulation of antimomy in three plant species and determine the usefulness of these species as bioindicators.
Notes:

Reference: Bell et al., 1997

Analytes Considered: Cd
Species: peanut, navy bean, soybean, maize
Geographic Location of Study: Australia lab and field
Exposure Duration: till plant maturity
Type of Tissue Analyzed: seeds
Type of Source Media Analyzed: soil
Analytical Method: AAS
Extraction Method: EDTA/HNO3
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: pH, CEC, Org. C, EC
Purpose of Study: To determine inter and intra-specific variations in accumulation of cadmium by peanut, soybean, and navybean.
Notes:

Reference: Beyer et al., 1985
Analytes Considered: Pb, Zn, Cu, Cd,
Species: Invertebrates, amphibians, small mammals and birds
Geographic Location of Study: Pennsylvania, USA
Exposure Duration: field
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: Soil, plants and fungi
Analytical Method: AAS
Extraction Method: Acid leached
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: pH, OM, P, CA, Mg, K and CEC
Purpose of Study: To examine the level of metal concentrations in wildlife and determine the effects on contamination on the health of the animals.
Notes:

Reference: Beyer et al., 1990
Analytes Considered: Pb, Zn, Cu, Se, Ni, Cd, Cr, As
Species: Common reed, ladybug, slugs, invertebrates, meadow vole, sparrow, mouse, shrew
Geographic Location of Study: Maryland
Exposure Duration: field
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: Soil
Analytical Method: AAS
Extraction Method: nitric acid and hydrogen peroxide or nitric acid and hydrochloric acid (samples) hydrochloric:nitric acid (soil)
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: To investigate trace elements in soil and biota in confined disposal facilities for dredged material
Notes:

Reference: Binet et al., 2000
Analytes Considered: PAH
Species: Ryegrass
Geographic Location of Study: Lab

Exposure Duration: 40 days
Type of Tissue Analyzed: roots
Type of Source Media Analyzed: soil
Analytical Method: GC-MS
Extraction Method: chloroform
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: %OM=2.9
Purpose of Study: To determine the fate of PAH in the rhizosphere and mycorrhizosphere of ryegrass
Notes: Calculated PAH concentration in plant using dry weight data and residual PAH in root.

Reference: Cappon, 1987
Analytes Considered: Hg, Se
Species: head lettuce, leafy lettuce, Swiss chard, Spinach, beet, carrot, onion, radish, turnip, broccoli, cabbage, bean, cucumber, pepper, squash, tomato
Geographic Location of Study: lab study
Exposure Duration: until maturity
Type of Tissue Analyzed: edible parts; leafy, tuberculosis, cole, pod, fruit
Type of Source Media Analyzed: soil
Analytical Method: gas liquid chromatography
Extraction Method: not specified
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: pH, texture
Purpose of Study: To provide information on the uptake of mercury and selenium in a variety of vegetable crops on soil with a known history of compost treatment under residential gardening.
Notes: The soil was cropped for 6 years with additions of compost. The data presented is for the sixth year with soil concentrations but compost concentrations are not presented.

Reference: Carter, A., 1983
Analytes Considered: Cd, Cu, Zn
Species: Soil invertebrates
Geographic Location of Study: Vancouver, British Columbia
Exposure Duration: field
Type of Tissue Analyzed: whole body, food items and fecies
Type of Source Media Analyzed: soil and plants
Analytical Method: AAS and flame spectroscopy
Extraction Method: Nitric Acid
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: Evaluate the importance of soil macrofauna in the distribution and turnover of heavy metals
Notes:

Reference: Cieslinki et al., 1996
Analytes Considered: Cd
Species: durum wheat (*Triticum turgidum*) and flax (*Linum usitatissimum*)
Geographic Location of Study: lab study
Exposure Duration: 7 weeks

Type of Tissue Analyzed: leaves and heads
Type of Source Media Analyzed: soil
Analytical Method: AAS
Extraction Method: nitric acid
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: pH, CEC, Ca, Texture, %sand, silt and clay.
Purpose of Study: To determine cadmium uptake in selected cultuvars of durum wheat and flax as affected by soil type.
Notes: Detect limits were not given.

Reference: Crawford et al., 1995
Analytes Considered: Cd, Cu, Zn
Species: Aphid (aphis fabae)
Geographic Location of Study: Lab
Exposure Duration: 14 days
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: plants
Analytical Method: AAS
Extraction Method: HNO_3
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: To determine the effects of elevated cadmium and copper in host plants to aphids.
Notes:

Reference: Devkota and Schmidt, 1999
Analytes Considered: Hg, Cd, Pb
Species: Acridid Grasshoppers (Insecta, Caelifera)
Geographic Location of Study: Lab
Exposure Duration: 5 weeks
Type of Tissue Analyzed: Whole body
Type of Source Media Analyzed: sand
Analytical Method: Zeeman AAS, Perkin-Elmer flame AAS
Extraction Method: solid sampling, aqua regia (Hg)
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: To determine effects of heavy metals on acridid grasshoppers during embryonic development
Notes: BAFs were reported in study but not raw data was given.

Reference: Dmowski, K. and M. A. Karolewski, 1979
Analytes Considered: Zn, Cd, Pb
Species: Invertebrates, amphibians and birds
Geographic Location of Study: Poland
Exposure Duration: field
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: Soils and plants
Analytical Method: Atomic absorption spectrophotometer
Extraction Method: HCL and HNO_3

Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: Examine contaminant concentrations in organisms representing different trophic levels to determine the role of chosen organisms in bioaccumulation of the contimanints.
Notes: Invertebrates analyzed in groups due to small mass. For birds, feathers and the liver were analyzed separate from the whole body, but results from each of the three samples were utilized in the calculation of total metals.

Reference: Edwards et al. 1982
Analytes Considered: Anthracene (PAH)
Species: *Glycine max*
Geographic Location of Study: Lab
Exposure Duration: 1.6, 3.5, 5.2, 22, 48 and 119 hours
Type of Tissue Analyzed: Whole plants
Type of Source Media Analyzed: solution culture
Analytical Method: ^{14}C and TLC analysis
Extraction Method: NA
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: Examine assimilation of PAHs by roots and/or leaves and the translocation to other plant parts.
Notes: Analysis of stems and leaves only for plants from the 1.6 hour harvest

Reference: Fazeli et al., 1998
Analytes Considered: Cu, Zn, Pb, Ni, Co, Cd, Cr
Species: rice
Geographic Location of Study: Nanjangud, India
Exposure Duration: resident
Type of Tissue Analyzed: leaf and seed
Type of Source Media Analyzed: soil
Analytical Method: AAS and coupled plasma spectrometer
Soil Extraction Method: HNO3
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented:
Purpose of Study: To understand the pathways of metals transfer from soil to plant, the uptake of metals by different parts of the plant, and the survival of paddy crops irrigated by paper mill effluent in Nanjangud, India.
Notes:

Reference: Fresquez et al., 1998
Analytes Considered: Radionuclidies, including Uranium
Species: Pinto beans, sweet corn and zucchini squash
Geographic Location of Study: Los Alamos, New Mexico, USA
Exposure Duration: field
Type of Tissue Analyzed: Fruits and foliage (stems and leaves)
Type of Source Media Analyzed: Soil
Analytical Method: See Fresquez et al., 1995
Extraction Method: NA
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA

Purpose of Study: To determine the level of risk from crops grown in soils contaminated with various radionuclides.
Notes:

Reference: Garcia et al. 1996
Analytes Considered: Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn
Species: grasses
Geographic Location of Study: Biscay Bay, Spain
Exposure Duration: field
Type of Tissue Analyzed: leaves
Type of Source Media Analyzed: Soil
Analytical Method: AAS
Extraction Method: DPTA
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: pH, CEC, OM and carbonate.
Purpose of Study: To assess the influence of distance from a roadside and traffic volume on metal concentrations in soils and grasses.
Notes:

Reference: Hemminga et al., 1989
Analytes Considered: Cd, Cu
Species: Aster tropolium (marsh plant) , Agapanthia villosoviridescens (larvae)
Geographic Location of Study: Netherlands
Exposure Duration: field
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: soil, plant (diet)
Analytical Method: Described in Nieuwenhuize et al. 1988
Soil Extraction Method: Described in Nieuwenhuize et al. 1988
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NR
Purpose of Study: To determine seasonal changes of cadmium and copper levels in stem boring larvae.
Notes:

Reference: Hope et al., 1996
Analytes Considered: Ba
Species: Ground dwelling insects, vegetation
Geographic Location of Study: Virginia
Exposure Duration: field
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: soil
Analytical Method: Done by Savanah River and Babcock and Wilcox Laboratories
Extraction Method: Done by Savanah River and Babcock and Wilcox Laboratories
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NR
Purpose of Study: To investigate the uptake and trophic transfer of barium in terrestrial ecosystems.
Notes:

Reference: Hossner et al., 1992
Analytes Considered: Se
Species: sideoats gramma grass (*Bouteloua curtipendula),* buffalograss (*Buchloe dactyloides),* bermudagrass (*Cynoden dactylon*), lovegrass (*Eragrostis trichodes*), kleingrass (*Panicum colartum),* vine mesquite (*Panicum obtusum),* switchgrass (*Panicum virgatum*), little bluestem (*Schizachyrium scoparium),* plains bristlegrass (*Setaria leucopila),* sand dropseed (*Sporobulus cryptandrus),*
Geographic Location of Study: lab study Foresville, Texas
Exposure Duration: 3 weeks and 4 weeks
Type of Tissue Analyzed: shoots
Type of Source Media Analyzed: soil
Analytical Method: AAS
Extraction Method: HNO3
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: pH, EC, and Texture
Purpose of Study: To determine selenium uptake and growth of 10 range plants propagated in uranuim mine soils in Floresville, Texas.
Notes: Two harvest were taken with the same soils and plants, the first one after 3 weeks and the second one after 4 weeks.

Reference: Hunter B. A. and M. S. Johnson, 1982
Analytes Considered: Cd, Cu
Species: small mammals and invertebrates
Geographic Location of Study: England
Exposure Duration: field
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: soils, litter, vegetation, fruits and seeds
Analytical Method: atomic absorption spectrophotometry
Extraction Method: nitric and perchloric wet extraction
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: Examination of food chain transfer of contaminants in a grassland ecosystem, and assess the relative transport and bioaccumulation potential.
Notes:

Reference: Hunter et al., 1987
Analytes Considered: Cd, Cu
Species: grasshopper (*Chorthippus brunneus*)
Geographic Location of Study: England
Exposure Duration: field
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: grass
Analytical Method: AAS
Extraction Method: nitric acid
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: To determine metal accumulation in grasshoppers
Notes:

Reference: Hussain and Jamil, 1992

Analytes Considered: Cd, Pb, Zn, Hg
Species: Water Hyacinth Weevils (Neochetina eichhornae)
Geographic Location of Study: lab
Exposure Duration: one week
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: leaves of water hyacinth
Analytical Method: AAS
Extraction Method: HCl
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NR
Purpose of Study: To investigate appearance of new proteins in water hyacinth weevils under the influence of metal bioaccumulation
Notes:

Reference: Jamil and Hussain, 1992
Analytes Considered: Cd, Zn, Mn, Hg
Species: Insect-*Neochetina eichhornae*
Geographic Location of Study: lab
Exposure Duration: 7 days
Type of Tissue Analyzed: Whole body
Type of Source Media Analyzed: leaves, root, petioles
Analytical Method: Perkin-Elmer flame AAS, inductive couple plasma-emission spectrophotometer for Hg
Extraction Method: HCl
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: To investigate the biotransfer of metals to insects via aquatic plants
Notes: Also has water, root, and petiole concentrations.

Reference: Joosse and Buker, 1979
Analytes Considered: Pb
Species: Collembola (*Orchesella cincta*)
Geographic Location of Study: Netherlands
Exposure Duration: 1 to 14 days
Type of Tissue Analyzed: whole body, exuviae, faeces, gut epithelium
Type of Source Media Analyzed: algae
Analytical Method: AAS
Soil Extraction Method: nitric acid and perchloric acid
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: To investigate lead uptake in Collembola
Notes: Species were exposed and then fed clean food for varying numbers of days afterword.

Reference: Jung and Thornton, 1996
Analytes Considered: Cd, Cu, Pb, Zn
Species: corn
Geographic Location of Study: Korea
Exposure Duration: field
Type of Tissue Analyzed: corn grain

Type of Source Media Analyzed: soil
Analytical Method: nitric and perchloric acid (soil), nitric acid (plant)
Extraction Method: ICP-AES
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: pH=5.6, CEC=5.2
Purpose of Study: To determine the contamination of soils and plants near a lead-zinc mine
Notes:

Reference: Jung and Thornton, 1997
Analytes Considered: Cd, Cu, Pb, Zn
Species: Rice (*Oryza sativa*)
Geographic Location of Study: Korea
Exposure Duration: 150 days
Type of Tissue Analyzed: stalks and grain
Type of Source Media Analyzed: soil
Analytical Method: ICP atomic emission spectometry
Extraction Method: nitric acid and perchloric acid
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: PH=5.3-5.5, CEC=7.9-13.2
Purpose of Study: To investigate seasonal variation of metal contamination in soils, plants, and water in paddy fields around a Pb-Zn mine
Notes:

Reference: Kay and Haller, 1986
Analytes Considered: Pb, Cd, Cu
Species: Waterhyacinth weevils
Geographic Location of Study: lab
Exposure Duration: 10 days
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: waterhyacinth
Analytical Method: AAS
Extraction Method: HCl
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: To determine bioaccumulation of heavy metals in weevils feeding on waterhyacinth
Notes:

Reference: Kipopoulou et al., 1999
Analytes Considered: PAHs
Species: Plants
Geographic Location of Study: Greece
Exposure Duration: field
Type of Tissue Analyzed: Inner vegetable tissue
Type of Source Media Analyzed: Soil
Analytical Method: HPLC
Extraction Method: Florisil-solid phase extraction
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: Investigate the relationship between PAHs accumulated in vegetables and their concentrations in the growing environment

Notes:

Reference: Kitao et al., 2000
Analytes Considered: Mn
Species: Japanese white birch (*Betula platyphylla*)
Geographic Location of Study: lab study in Japan
Exposure Duration: 30 days
Type of Tissue Analyzed: leaves
Type of Source Media Analyzed: water
Analytical Method: AAS
Extraction Method: HClO4 andHNO3
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented:
Purpose of Study: To evaluate the possibility of using Japanese white birch as a bioindicator to detect Mn toxicity using foliar symptoms.
Notes: The seventh youngest leaf was used for each sample because it was old enough to be mature, but young enough not to senesce. The leaves were about 30 days old.

Reference: Knigge andKohler, 2000
Analytes Considered: Pb
Species: arthropod (isopoda: *P. Scaber*)
Geographic Location of Study: Tubingen, Germany
Exposure Duration: 80 days
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: leaf litter
Analytical Method: atomic absorption spectrophotometer (AAS)
Extraction Method: Nitric acid
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: To determine the impact of lead on nutrition, energy reserves, respiration and stress protein.
Notes: Populations in lab were collected from field sites. The non-pre-exposed group was collected from a control site while the pre-exposed group was collected from a lead contaminated site. The contaminated site had average lead soil concentration of 748 mg/kg and an average lead concentration of 153 mg/kg in rotten wood, the predominant diet source.

Reference: Knutti et al., 1988
Analytes Considered: Cd
Species: invertebrates, mouse, roe-deer
Geographic Location of Study: Switzerland
Exposure Duration: field
Type of Tissue Analyzed: whole body, liver, kidney
Type of Source Media Analyzed: litter
Analytical Method: AAS
Extraction Method: nitric acid
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NR
Purpose of Study: To determine cadmium content in invertebrate fauna of an unpolluted forest in Switzerland

Reference: Lindqvist, 1992
Analytes Considered: Cd, Cu, Zn
Species: Phytophagus insects
Geographic Location of Study: Sweden
Exposure Duration: field
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: plants
Analytical Method: AAS
Extraction Method: nitric acid
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: To determine accumulation of cadmium, copper, and zinc in phytophagus insects
Notes: larvae were reared in laboratory on plants collected from the site.

Reference: Lombi et al., 1998
Analytes Considered: Cd, Cu, Ni, V, Zn
Species: sunflower (*Helianthus annuus*)
Geographic Location of Study: lab study in Austria
Exposure Duration: 40 days
Type of Tissue Analyzed: leaf and seed
Type of Source Media Analyzed: soil
Analytical Method: AAS and inductive coupled plasma emission spectrometry
Extraction Method: nitric-perchloric acid/aqua regia
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: Soil Type (FAO), % sand, silt and clay, pH, % OM, total nitrogen, % CaCo3, CEC, P2O5, K20.
Purpose of Study: To determine the mobility of Cd, Cu, Ni, V and Zn in soil and their uptake by sunflowers grown at different contamination levels.
Notes: Contaminated soil was incubated for 4 months then diluted by adding 2 parts noncontaminated soil to 3 parts contaminated soil before planting sunflowers.

Reference: Mortvedt, J. J., 1994
Analytes Considered: U
Species: Plants
Geographic Location of Study: NA
Exposure Duration: NA
Type of Tissue Analyzed: Roots and Shoots
Type of Source Media Analyzed: Soil
Analytical Method: NA
Extraction Method: NA
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: Review and summarize some of the literature on soil plant relationships to certain radionuclides
Notes: Review and data summary from previous studies.

Reference: Odendaal and Reinecke, 1999
Analytes Considered: Cd

Species: *Porcellio laevis*
Geographic Location of Study: lab
Exposure Duration: 8 weeks
Type of Tissue Analyzed: whole body, hepatopancreas
Type of Source Media Analyzed: leaves
Analytical Method: flame atomic absorption spectrophotometer
Extraction Method: Nitric acid
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: Investigate accumulation and sublethal effects of cadmium on terrestrial isopods
Notes:

Reference: Paine et al., 1993
Analytes Considered: PCBs
Species: house cricket (*Acheta domesticus*)
Geographic Location of Study: Illinois
Exposure Duration: 14 days
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: soil
Analytical Method: Hewelett Packard 5890 series II GC fitted with an electron-capture detector, auto injector, and 30-m DB-5 column
Extraction Method: methylene chloride : cyclohexane
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: pH=5.5, 4% OM
Purpose of Study: To determine the toxicity and bioaccumulation potential of PCBs to crickets
Notes: Concentrations in crickets are reported as wet weights.

Reference: Palazo and Legget, 1986
Analytes Considered: TNT, 2ADNT, 4ADNT
Species: yellow nutsedge (*Cyperus esculentus*)
Geographic Location of Study: Lab
Exposure Duration: 42 days
Type of Tissue Analyzed: roots, tubers, leaves, rhizomes
Type of Source Media Analyzed: water
Analytical Method: HPLC (water), ECGC (plant)
Extraction Method: benzene (plant)
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: To determine the effect and disposition of TNT in a terrestrial plant
Notes:

Reference: Pascoe et al., 1996
Analytes Considered: As, Cd, Cu, Zn
Species: vegetation, grasshoppers
Geographic Location of Study: Montana
Exposure Duration: field
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: soil

Analytical Method: ICP and AAS
Extraction Method: reported in Linder et al., 1994
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NR
Purpose of Study: To perform a food chain analysis of exposures and risk to wildlife at a metals contaminated wetland.
Notes:

Reference: Pettersson et al., 1993
Analytes Considered: ^{238}U, ^{234}U, ^{230}Th, ^{226}Ra, ^{210}Pb, ^{210}Po, ^{232}Th, ^{228}Th
Species: waterlily (*Nymphaea violacea)*
Geographic Location of Study: Northwest Territory, Australia
Exposure Duration: resident
Type of Tissue Analyzed: foliage
Type of Source Media Analyzed: sediment
Analytical Method: alpha-spectometry
Extraction Method: radiochemically digested
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented:
Purpose of Study: To identify the major source of radionuclide uptake by the plant, to assess the concentration factors/ratios needed for predicting radiation exposure of waterlilies and to estimate radiation exposure of the public from consumption of waterlilies near a uranium mine in the Northern Territory of Australia.
Notes: BAF's are given as waterlily foliage wet weight to wet weight sediment concentration ratios.

Reference: Pinochet et al., 1999
Analytes Considered: Se, Cu
Species: Alfalfa, grass, quince, grape, cabbage, garlic, onion, carrot, lettuce, yuyo, llantencillo, celery
Geographic Location of Study: Chile
Exposure Duration: Field
Type of Tissue Analyzed: whole body, fruit, or leaf
Type of Source Media Analyzed: soil
Analytical Method: acid digestion, HCl for Se
Extraction Method: AAS
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented:
Purpose of Study: to determine uptake of selenium and copper after long term exposure in vegetables and fruits
Notes:

Reference: Posthuma, 1990
Analytes Considered: Cd, Zn
Species: Collemboal (Orchesella cincta)
Geographic Location of Study: Netherlands, Germany, Belgium
Exposure Duration: field
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: soil, plant
Analytical Method: graphite furnace AAS

Extraction Method: HNO3 and H2O2
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: To determine genetic differentiation b/c populations of Orshesella cincta from heavy metal contaminated sites.
Notes:

Reference: Posthuma et al., 1992
Analytes Considered: Cd
Species: Orchesella cincta
Geographic Location of Study: lab
Exposure Duration: 7 weeks, 3 days
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: food medium
Analytical Method: HNO_3 and H_2O_2
Extraction Method: Described in Van Straalen and Van Wensem, 1986
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: To determine population differentiation in Orchesella cincta from metal contaminated sites
Notes: Populations used were collected from 7 sites. Sites 1 and 2 were reference sites. Data used in database used reference site populations. Data was converted from that presented.

Reference: Price et al., 1974
Analytes Considered: Pb
Species: Arthropods
Geographic Location of Study: Urbana, Illinois, USA
Exposure Duration: field
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: soil and plants
Analytical Method: Atomic absorption spectrophotometry
Extraction Method: HCL
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: Examination of the potential for storage and movement of contaminates in the insect component of the ecosystem
Notes:

Reference: PTI Environmental Services, 1994
Analytes Considered: aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, selenium, silver sodium, thallium, total mercury, vanadium, zinc
Species: spider, grasshopper, caterpillar, beetle
Geographic Location of Study: Upper Clark Fork River Basin
Exposure Duration: resident
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: soil
Analytical Method: ICP/CLP SOW 788 (U.S. EPA 1988)
Extraction Method: HNO3/modified EPA SW-846 Method 3050 using an additional quantity of acid

Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: pH, CEC, % sand, silt, clay, gravel, EC, sulfate, %TOC.
Purpose of Study: To assess ecorisks for the Upper Clark Fork River Basin.
Notes: The invertebrate sample included 10 individuals or 4 grams of tissue.

Reference: PTI Environmental Services, 1995
Analytes Considered: aluminum, antimony, barium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, silver, sodium, vanadium, zinc.
Species: *Smilex bona-nox, Bidens polylepis, Ambrosia trifida, Ambrosia artemisiifolia, Sorghastrum nutans, Panicum virgatum, Ambrosia psilostachya, Amaranthus palmeri*
Geographic Location of Study: Bartlesville, Oklahoma
Exposure Duration: resident
Type of Tissue Analyzed: aboveground parts
Type of Source Media Analyzed: soil
Analytical Method: Done by CAS Analytical Laboratories
Extraction Method: Done by CAS Analytical Laboratories
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: pH, MEC, and P
Purpose of Study: To assess the ecological risks in Bartlesville, Oklahoma
Notes: CEC is given as MEC. SONV was assumed to be *Sourghastrum nutans.*

Reference: Rabitsch, 1995a
Analytes Considered: Cd, Pb, Cu, Zn
Species: Invertebrates
Geographic Location of Study: Austria
Exposure Duration: field
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: soil and plants
Analytical Method: AAS
Extraction Method: nitric acid
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: pH
Purpose of Study: To provide information on the standard level of contaminants in invertebrates living in close proximity to an emissions source with a long history of pollution.
Notes:

Reference: Rabitsch, 1995b
Analytes Considered: Cd, Pb, Cu, Zn
Species: Dolichorderinae spp., Myrmicinae spp., Formicinae spp.
Geographic Location of Study: Austria
Exposure Duration: field
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: soil
Analytical Method: Varian Spectr AA 30 with a GTA 96 autosampler
Extraction Method: nitric acid
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NR
Purpose of Study: To determine metal accumulation in arthropods

Notes:

Reference: Rabitsch, 1995c
Analytes Considered: Pb, Zn, Cu, Cd
Species: Arachnidae
Geographic Location of Study: Austria
Exposure Duration: field
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: soil
Analytical Method: Varian Spector AA30 with GTA 96 autosampler
Extraction Method: nitric acid
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: To determine metal accumulation in arthropods exposed to heavy metals
Notes: soil concentrations were extracted from Rabitsch, 1995b.

Reference: Ramirez and Rogers, 2000
Analytes Considered: Al, As, B, Ba, Be, Cd, Cr, Cu, Fe, Hg, Mg, Mn, Mo, Ni, Pb, Se, Sr, V, Zn
Species: Grasshoppers, vegetation, birds
Geographic Location of Study: Wyoming
Exposure Duration: field
Type of Tissue Analyzed: liver, eggs, whole body
Type of Source Media Analyzed: soil, water
Analytical Method: AAS for As, Hg, Se, ICPES for others
Extraction Method: nitric and perchloric acids (all except Hg) nitric acid for Hg
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NR
Purpose of Study: To investigate selenium in a Wyoming Grassland community receiving an In Situ Uranium Mine
Notes:

Reference: Schneider et al., 1995
Analytes Considered: TNT, RDX
Species: Plants
Geographic Location of Study: Middleton, Iowa, USA
Exposure Duration: field
Type of Tissue Analyzed: Roots and Shoots
Type of Source Media Analyzed: Soil
Analytical Method: HPLC
Extraction Method: dichloromethane
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: To determine the uptake under natural under natural environmental conditions of explosive compounds and their derivatives by plants.
Notes:

Reference: Sheppard et al., 1984
Analytes Considered: U
Species: alfalfa (*Medicago sativa*) and Swiss chard (*Beta vulgaris*)

Geographic Location of Study: lab study
Exposure Duration: 74 days
Type of Tissue Analyzed: aboveground parts
Type of Source Media Analyzed: soil
Analytical Method: AAS
Extraction Method: HNO3
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: pH, EC, and Texture, field capacity, bulk density.
Purpose of Study: To determine selenium uptake and growth of 10 range plants propagated in uranuim mine soils in Floresville, Texas.
Notes:

Reference: Sheppard et al., 1989
Analytes Considered: Uranium
Species: plants (blueberries, corn, spinach, barley, potato, wild rice)
Geographic Location of Study: Manitoba
Exposure Duration: until plants reached edible maturity
Type of Tissue Analyzed: seed/leat
Type of Source Media Analyzed: soil
Analytical Method: NA/DNC
Extraction Method: NA
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: pH, CEC
Purpose of Study: To determine uptake of natural radionuclides by field and garden crops
Notes: Only CR values given

Reference: Sheppard and Evenden, 1985
Analytes Considered: U
Species: Barley (*Hordeum vulgare*)
Geographic Location of Study: lab study in Canada
Exposure Duration: 53 days
Type of Tissue Analyzed: aboveground parts
Type of Source Media Analyzed: soil
Analytical Method: delayed neutron counting for plants
Extraction Method: NaHCO3 and CaCl2 for soil
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: pH, texture, NO3N, P, K, CEC.
Purpose of Study: To study plant uptake of various elements placed above, at or below a shallow water table using barley and elements whose solubilities vary with redox potential.
Notes: The experiment utilized lysimeters to create 1 constant water table and one that fluctuated to up to 16cm below the soil surface. The analytical method for soil analysis was not given.

Reference: Sheppard and Evenden, 1988
Analytes Considered: U, Pb, Th
Species: Plants
Geographic Location of Study: review paper
Exposure Duration: review paper

Type of Tissue Analyzed: plant
Type of Source Media Analyzed: soil
Analytical Method: review paper
Extraction Method: review paper
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: review paper
Purpose of Study: Critical compilation and review of plant/soil CRs for U, Th, and Pb
Notes: This paper compiled several CRs and calculated a weighted average for CRs based on all located studies. References several individual studies in appendix.

Reference: Sheppard and Evenden, 1990
Analytes Considered: Al, Ba, Co, Cu, Fe, Ni, Pb, Th, Ti, U, Zn, Zr
Species: sweet lowbush blueberry (*Vaccinium angustifolium)*
Geographic Location of Study: Canada
Exposure Duration: resident
Type of Tissue Analyzed: leaf
Type of Source Media Analyzed: soil
Analytical Method: AA/inductively coupled plasma spectroscopy/NAG
Extraction Method: HNO3/aqua regia and HF
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented:
Purpose of Study: To characterize plant concentration ratios in a 64-site field survey across the range of sweet lowbrush bueberry for 23 elements.
Notes:

Reference: Sheppard and Sheppard, 1991
Analytes Considered: Pb
Species: blueberries
Geographic Location of Study: Canada
Exposure Duration: field
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: soil
Analytical Method: ICP spectroscopy
Extraction Method: HNO_3 : $HclO_4$ (plants), aqua regia (soil)
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NR
Purpose of Study: To determine the uptake of lead in plants living in Boreal soils
Notes:

Reference: Semu et al., 1985
Analytes Considered: Hg
Species: Wheat (*Triticum aestivum*) and beans (*Phaseolus vulgaris*)
Geographic Location of Study: lab study
Exposure Duration: until maturity
Type of Tissue Analyzed: grain
Type of Source Media Analyzed: soil
Analytical Method: gamma scintillation counting/AAS
Extraction Method: HNO3 and KBr O3
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: pH, CEC, Organic C, Total N, % Clay.

Purpose of Study: To determine the uptake of mercury by wheat and navy beans grown on an oxisol treated with two mercury compounds.
Notes: Beans failed to germinate at 50 mg Hg/kg.

Reference: Steinborn and Breen, 1999
Analytes Considered: Cu, Zn, Pb
Species: *Hylocomium splendens, Rhytidiadelphus lorues, Teucrium scorodonia, Primula vulgaris, Succissa pratensis*
Geographic Location of Study: Silvermines, Colorado
Exposure Duration: resident
Type of Tissue Analyzed: leaf and shoot
Type of Source Media Analyzed: soil
Analytical Method: AAS
Extraction Method: HNO3-HCL
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: pH
Purpose of Study: To investigate lead zinc and copper in soil, three higher plant species and two moss species at Silvermines, Colorado.
Notes: Values of pH were given as ranges and the median value was calculated.

Reference: Tam et al., 1995
Analytes Considered: Cu, Cd, Pb, Cr, Zn, Mn
Species: *Kandelia candel* and *Aegiceras corniculatum*
Geographic Location of Study: Shenzhen, China
Exposure Duration: field
Type of Tissue Analyzed: Leaves
Type of Source Media Analyzed: Soil
Analytical Method: AAS
Extraction Method: nitric acid
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: K, organic C, P, N, CEC
Purpose of Study: To investigate the level of heavy metals in mangrove ecosystems and to evaluate the spatial and temporal variations of these elements in sediments and leaves.
Notes:

Reference: Thompson et al., 1999
Analytes Considered: RDX
Species: Poplar trees
Geographic Location of Study: Lab
Exposure Duration: 2-7 days
Type of Tissue Analyzed: root, stem, leaves
Type of Source Media Analyzed: water
Analytical Method: HPLC isocratic pump, spectra 100 ultraviolet light detector, injection loop volume (water and plants)
Extraction Method: acetone (plants)
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: To investigate translocation of RDX in poplar trees
Notes: plants were grown hydroponically

Reference: Van Hook and Yates, 1975
Analytes Considered: Cd
Species: crickets (*P. Fasciatus*) and wolf spiders (Lycosa spp.)
Geographic Location of Study: Tennessee
Exposure Duration: field
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: soil
Analytical Method: Nuclear data gamma spectometer system
Extraction Method: NA
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NR
Purpose of Study: To investigate the behavior of cadmium in a grassland arthropod food chain.
Notes: Study used cadmium 109.

Reference: Watson et al., 1976
Analytes Considered: Pb. Zn, Cd, Cu
Species: Omnivores: Formicidae-dlichoderinae, formicinae, myrmicinae
Orthoptera-Blattidae
Coleoptera-Tenebrionidae
Fungivores: Coleoptera-derodontidae, pselaphidae, ptiliidae, orthoperidae
Collembola-Entonbryidae
Diptera-Drosphilidae, sciaridae, scatopsidae
Hemiptera-aradidae
Thysanoptera-phloeothripidae
Litter grazers: Diptera-bibionidae, cecidomyidae
Chordeumida
Predators: Coleoptera-carabidae, coccinnellidae, lampyridae, staphylinidae, cantharidae, elateridae
Diptera-ceratopogonidae, dolichopodidae, rhagionidae, stratiomyidae, syrphidae
Hemiptera-reduviidae
Hymenoptera-ampulicidae, braconidae,chalcidoidea, eulophidae, eupelmidae, formicidae, dorylinae, ponerinae, ichneumonidae, proctotrupoidea
Neuroptera-ascalaphidae, chrysopidae, hemerobiidae
Araneae-agelenidae, anyphaenidae, clubionidae, dysderidae, gnaphosidae, hahniidae, linyphiidae, micryphantiinae, linyphiinae, lycosidae, oecobiidae, oonopidae, salticidae, thomisidae, zoridae
Phalangida-phalangididae
Pseudoscorpionidae
Geophilmorpha
Lithobiomorpha-henicopidae, lithobiidae
Detritivores: Coleoptera-nitidulidae, scarabeidae, silphidae, staphylinidae, silphidae, staphylinidae, elateridae, lagriidae, orthoperidae, tenebrionidae
Collembola-poduridae
Diplura- campodeidae, japygidae

Diptera-phoridae, sarcophagidae, tipulidae, muscidae, stratiomyidae, syrphidae, tipulidae, trichorceridae
Isoptera
Protura
Psocoptera
Arachnida-phalangida

Geographic Location of Study: Missouri
Exposure Duration: field
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: Litter
Analytical Method: AAS
Extraction Method: HNO_3:$HClO_4$
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: To investigate the impact of a lead mining smelting complex on the forest floor litter arthropod fauna int he new lead belt region of southeast Missouri
Notes: Geometric means were calculated for litter metal concentration from raw data in study

Reference: Wieser et al., 1976
Analytes Considered: Cu
Species: *Tracheoniscus rathkei* (Isopoda) and *Oniscus asellus* (Isopoda)
Geographic Location of Study: Austria
Exposure Duration: field
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: soil, litter
Analytical Method: zinc-dibenzyldithiocarbmate
Extraction Method: sulfuric acid and hydrogen peroxide, or homogenized in water and extracted with CTC
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NR
Purpose of Study: To investigate relationship between Cu in the environment and the distribution and concentration of Cu in two species of isopods.
Notes:

Reference: Wieser et al., 1977
Analytes Considered: Cu
Species: Isopoda spp.
Geographic Location of Study: Austria
Exposure Duration: field
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: soil, litter
Analytical Method: see Dallinger and Weiser, 1977
Extraction Method: see Dallinger and Weiser, 1977
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NR
Purpose of Study: To investigate the flow of copper through a terrestrial food chain and the factors influencing the copper content of isopods
Notes: This paper is one of a three paper series including Wieser and Dallinger, 1977 and Dallinger, 1977

Reference: Wild S. R. and K. C. Jones, 1992
Analytes Considered: PAHs
Species: *Dacus carota*
Geographic Location of Study: England
Exposure Duration: field
Type of Tissue Analyzed: Roots and Shoots
Type of Source Media Analyzed: Soil
Analytical Method: HPLC
Extraction Method: dichloromethane
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: Investigate the uptake of PAHs from sewage sludge amended soils
Notes:

Reference: Witzel, 1998
Analytes Considered: Cd, Pb
Species: *Porcellio. scaber*
Geographic Location of Study: Lab
Exposure Duration: 6 months
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: hornbeam leaves
Analytical Method: AAS
Extraction Method: nitric acid
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: NA
Purpose of Study: To investigate the uptake, storage, and loss of cadmium and lead in the woodlouse
Notes:

Reference: Yaman, 2000
Analytes Considered: Ni
Species: Fruits
Geographic Location of Study: Turkey
Exposure Duration: field
Type of Tissue Analyzed: whole body
Type of Source Media Analyzed: soil
Analytical Method: AAS
Extraction Method: acid digest
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: pH=6.4-6.6
Purpose of Study: to determine nickel speciation in soil and the relationship with its concentration in fruit
Notes:

Reference: Zellmer et al., 1995
Analytes Considered: TNT
Species: Plants
Geographic Location of Study: Will County, Illinois, USA
Exposure Duration: field

Type of Tissue Analyzed: roots and shoots
Type of Source Media Analyzed: soil
Analytical Method: HPLC
Extraction Method: dichloromethane
Soil Characteristics (pH, CEC, % OM, % Clay, etc.) Presented: OM, Ca, Mg, Na, K, CEC, TKN, C, P, pH
Purpose of Study: To assess the health hazards of TNT and its degradation products entering the food chain through the uptake by plants.
Notes:

APPENDIX B

Terrestrial Invertebrate and Plant Bioaccumulation Databases

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	*Species*	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Pb	Britain	control	field	resident	.	Insecta	Diptera	.	*diptera*	.	119.60	28.1	.	Andrews_et_al_1989a
Pb	Britain	tailings_dam	field	resident	.	Insecta	Diptera	.	*diptera*	.	3960.00	549	.	Andrews_et_al_1989a
Pb	Britain	control	field	resident	predator	Arachinida	Araneae	.	*spiders*	.	119.60	22.2	.	Andrews_et_al_1989a
Pb	Britain	tailings_dam	field	resident	predator	Arachinida	Araneae	.	*spiders*	.	3960.00	462	.	Andrews_et_al_1989a
Pb	Britain	control	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae*	.	119.60	5.7	.	Andrews_et_al_1989a
Pb	Britain	tailings_dam	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae*	.	3960.00	106	.	Andrews_et_al_1989a
Zn	Britain	control	field	resident	.	Insecta	Diptera	.	*diptera*	.	61.90	198	.	Andrews_et_al_1989b
Zn	Britain	tailings_dam	field	resident	.	Insecta	Diptera	.	*diptera*	.	1925.00	852	.	Andrews_et_al_1989b
Zn	Britain	control	field	resident	predator	Arachinida	Araneae	.	*spiders*	.	61.90	529	.	Andrews_et_al_1989b
Zn	Britain	tailings_dam	field	resident	predator	Arachinida	Araneae	.	*spiders*	.	1925.00	657	.	Andrews_et_al_1989b
Zn	Britain	control	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae*	.	61.90	120	.	Andrews_et_al_1989b
Zn	Britain	tailings_dam	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae*	.	1925.00	340	.	Andrews_et_al_1989b
F	Britain	control	field	resident	.	Insecta	Diptera	.	*diptera*	.	131.20	31	.	Andrews_et_al_1989c
F	Britain	tailings_dam	field	resident	.	Insecta	Diptera	.	*diptera*	.	98.88	1.148	.	Andrews_et_al_1989c
Cd	Pennsylvania	Bake_Oven_Knob	field	resident	detritivore	Diplopoda	.	.	*millepede-3*	.	2.70	2.1	.	Beyer_et_al_1985
Cd	Pennsylvania	Bake_Oven_Knob	field	resident	detritivore	Diplopoda	.	.	*millepede-2*	.	2.70	3	.	Beyer_et_al_1985
Cd	Pennsylvania	Bake_Oven_Knob	field	resident	detritivore	Diplopoda	.	.	*millepede-1*	.	2.70	4.5	.	Beyer_et_al_1985
Cu	Pennsylvania	Bake_Oven_Knob	field	resident	detritivore	Diplopoda	.	.	*millepede-3*	.	18.00	150	.	Beyer_et_al_1985
Cu	Pennsylvania	Bake_Oven_Knob	field	resident	detritivore	Diplopoda	.	.	*millepede-1*	.	18.00	160	.	Beyer_et_al_1985
Cu	Pennsylvania	Bake_Oven_Knob	field	resident	detritivore	Diplopoda	.	.	*millepede-2*	.	18.00	160	.	Beyer_et_al_1985
Pb	Pennsylvania	Bake_Oven_Knob	field	resident	detritivore	Diplopoda	.	.	*millepede-3*	.	150.00	19	.	Beyer_et_al_1985
Pb	Pennsylvania	Bake_Oven_Knob	field	resident	detritivore	Diplopoda	.	.	*millepede-1*	.	150.00	22	.	Beyer_et_al_1985
Pb	Pennsylvania	Bake_Oven_Knob	field	resident	detritivore	Diplopoda	.	.	*millepede-2*	.	150.00	27	.	Beyer_et_al_1985
Zn	Pennsylvania	Bake_Oven_Knob	field	resident	detritivore	Diplopoda	.	.	*millepede-3*	.	230.00	320	.	Beyer_et_al_1985
Zn	Pennsylvania	Bake_Oven_Knob	field	resident	detritivore	Diplopoda	.	.	*millepede-2*	.	230.00	370	.	Beyer_et_al_1985
Zn	Pennsylvania	Bake_Oven_Knob	field	resident	detritivore	Diplopoda	.	.	*millepede-1*	.	230.00	980	.	Beyer_et_al_1985
Cd	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Arctiidae	*Halisidota_and_spilosoma*	2.30	2.70	4.6	.	Beyer_et_al_1985
Cd	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Arctiidae	*lep._H._tessellaris*	8.10	35.00	11	.	Beyer_et_al_1985
Cu	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Arctiidae	*Halisidota_and_spilosoma*	7.10	18.00	6.2	.	Beyer_et_al_1985
Cu	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Arctiidae	*lep._H._tessellaris*	8.80	9.90	9.3	.	Beyer_et_al_1985
Pb	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Arctiidae	*Halisidota_and_spilosoma*	9.90	150.00	2	.	Beyer_et_al_1985
Pb	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Arctiidae	*lep._H._tessellaris*	31.30	41.00	6.8	.	Beyer_et_al_1985
Zn	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Arctiidae	*Halisidota_and_spilosoma*	148.00	230.00	340	.	Beyer_et_al_1985
Zn	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Arctiidae	*lep._H._tessellaris*	660.00	2900.00	500	.	Beyer_et_al_1985
Cd	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Lasiocampidae	*lep._M._americanum*	2.30	2.70	0.7	.	Beyer_et_al_1985
Cu	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Lasiocampidae	*lep._M._americanum*	7.10	18.00	12	.	Beyer_et_al_1985
Pb	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Lasiocampidae	*lep._M._americanum*	9.90	150.00	1.3	.	Beyer_et_al_1985
Zn	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Lasiocampidae	*lep._M._americanum*	148.00	230.00	150	.	Beyer_et_al_1985
Cd	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Lymantriidae	*lep.P._dispar*	2.30	2.70	0.77	.	Beyer_et_al_1985
Cd	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Lymantriidae	*lep._P._dispar*	8.10	35.00	3.3	.	Beyer_et_al_1985
Cu	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Lymantriidae	*lep._P._dispar*	7.10	18.00	13	.	Beyer_et_al_1985
Cu	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Lymantriidae	*lep._P._dispar*	8.80	9.90	13	.	Beyer_et_al_1985
Pb	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Lymantriidae	*lep._P._dispar*	9.90	150.00	3.4	.	Beyer_et_al_1985
Pb	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Lymantriidae	*lep._P._dispar*	31.30	41.00	8.7	.	Beyer_et_al_1985
Zn	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Lymantriidae	*lep._P._dispar*	148.00	230.00	170	.	Beyer_et_al_1985
Zn	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Lymantriidae	*lep._P._dispar*	660.00	2900.00	280	.	Beyer_et_al_1985
Cd	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._C._paleogama*	2.30	2.70	0.38	.	Beyer_et_al_1985
Cd	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._L._unipuncta*	2.30	2.70	0.38	.	Beyer_et_al_1985
Cd	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._A._pyramidoides*	2.30	2.70	0.64	.	Beyer_et_al_1985
Cd	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._N._c-nigrum*	2.30	2.70	1.7	.	Beyer_et_al_1985
Cd	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._C._paleogama*	8.10	35.00	0.72	.	Beyer_et_al_1985
Cd	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._L._unipuncta*	8.10	35.00	1.2	.	Beyer_et_al_1985
Cd	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._N._c-nigrum*	8.10	35.00	4.7	.	Beyer_et_al_1985
Cd	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._A._pyramidoides*	8.10	35.00	5.2	.	Beyer_et_al_1985

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	*Species*	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Cd	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._P._excaecatus*	8.10	35.00	8.3	.	Beyer_et_al_1985
Cu	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._L._unipuncta*	7.10	18.00	3.8	.	Beyer_et_al_1985
Cu	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._A._pyramidoides*	7.10	18.00	5.5	.	Beyer_et_al_1985
Cu	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._N._c-nigrum*	7.10	18.00	6.1	.	Beyer_et_al_1985
Cu	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._C._paleogama*	7.10	18.00	13	.	Beyer_et_al_1985
Cu	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._L._unipuncta*	8.80	9.90	7.2	.	Beyer_et_al_1985
Cu	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._A._pyramidoides*	8.80	9.90	9.5	.	Beyer_et_al_1985
Cu	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._P._excaecatus*	8.80	9.90	9.9	.	Beyer_et_al_1985
Cu	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._C._paleogama*	8.80	9.90	15	.	Beyer_et_al_1985
Cu	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._N._c-nigrum*	8.80	9.90	15	.	Beyer_et_al_1985
Pb	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._L._unipuncta*	9.90	150.00	1	.	Beyer_et_al_1985
Pb	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._C._paleogama*	9.90	150.00	1.5	.	Beyer_et_al_1985
Pb	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._A._pyramidoides*	9.90	150.00	1.7	.	Beyer_et_al_1985
Pb	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._N._c-nigrum*	9.90	150.00	1.9	.	Beyer_et_al_1985
Pb	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._L._unipuncta*	31.30	41.00	1.9	.	Beyer_et_al_1985
Pb	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._C._paleogama*	31.30	41.00	2.1	.	Beyer_et_al_1985
Pb	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._N._c-nigrum*	31.30	41.00	2.7	.	Beyer_et_al_1985
Pb	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._P._excaecatus*	31.30	41.00	3.3	.	Beyer_et_al_1985
Pb	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._A._pyramidoides*	21.30	41.00	4.8	.	Beyer_et_al_1985
Zn	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._A._pyramidoides*	148.00	230.00	140	.	Beyer_et_al_1985
Zn	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._C._paleogama*	148.00	230.00	160	.	Beyer_et_al_1985
Zn	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._L._unipuncta*	148.00	230.00	190	.	Beyer_et_al_1985
Zn	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._N._c-nigrum*	148.00	230.00	300	.	Beyer_et_al_1985
Zn	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._C._paleogama*	660.00	2900.00	250	.	Beyer_et_al_1985
Zn	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._L._unipuncta*	660.00	2900.00	320	.	Beyer_et_al_1985
Zn	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._P._excaecatus*	660.00	2900.00	380	.	Beyer_et_al_1985
Zn	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._N._c-nigrum*	660.00	2900.00	480	.	Beyer_et_al_1985
Zn	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Lepidoptera	Noctuidae	*lep._A._pyramidoides*	660.00	2900.00	540	.	Beyer_et_al_1985
Cd	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Coleoptera	Scolytidae	*bark_beetle_larvae*	.	2.70	1.5	.	Beyer_et_al_1985
Cd	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Coleoptera	Scolytidae	*bark_beetle_larvae*	.	35.00	6.2	.	Beyer_et_al_1985
Cu	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Coleoptera	Scolytidae	*bark_beetle_larvae*	.	18.00	28	.	Beyer_et_al_1985
Cu	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Coleoptera	Scolytidae	*bark_beetle_larvae*	.	9.90	22	.	Beyer_et_al_1985
Pb	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Coleoptera	Scolytidae	*bark_beetle_larvae*	.	150.00	0.1	.	Beyer_et_al_1985
Pb	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Coleoptera	Scolytidae	*bark_beetle_larvae*	.	41.00	0.1	.	Beyer_et_al_1985
Zn	Pennsylvania	Bake_Oven_Knob	field	resident	herbivore	Insecta	Coleoptera	Scolytidae	*bark_beetle_larvae*	.	230.00	470	.	Beyer_et_al_1985
Zn	Pennsylvania	Palmerton	field	resident	herbivore	Insecta	Coleoptera	Scolytidae	*bark_beetle_larvae*	.	2900.00	1450	.	Beyer_et_al_1985
Cd	Pennsylvania	Palmerton	field	resident	predator	Chilopoda	.	.	*centipede*	.	35.00	28	.	Beyer_et_al_1985
Cu	Pennsylvania	Palmerton	field	resident	predator	Chilopoda	.	.	*centipede*	.	9.90	41	.	Beyer_et_al_1985
Pb	Pennsylvania	Palmerton	field	resident	predator	Chilopoda	.	.	*centipede*	.	41.00	1.2	.	Beyer_et_al_1985
Zn	Pennsylvania	Palmerton	field	resident	predator	Chilopoda	.	.	*centipede*	.	2900.00	1180	.	Beyer_et_al_1985
Cd	Pennsylvania	Palmerton	field	resident	predator	Insecta	Diptera	Calliphoridae	*dip._Calliphoridae*	.	35.00	29	.	Beyer_et_al_1985
Cu	Pennsylvania	Palmerton	field	resident	predator	Insecta	Diptera	Calliphoridae	*dip._Calliphoridae*	.	9.90	18	.	Beyer_et_al_1985
Pb	Pennsylvania	Palmerton	field	resident	predator	Insecta	Diptera	Calliphoridae	*dip._Calliphoridae*	.	41.00	15	.	Beyer_et_al_1985
Zn	Pennsylvania	Palmerton	field	resident	predator	Insecta	Diptera	Calliphoridae	*dip._Calliphoridae*	.	2900.00	740	.	Beyer_et_al_1985
Cd	Pennsylvania	Palmerton	field	resident	predator	Insecta	Diptera	Sarcophagidae	*dip._Sarcophagidae*	.	35.00	44	.	Beyer_et_al_1985
Cu	Pennsylvania	Palmerton	field	resident	predator	Insecta	Diptera	Sarcophagidae	*dip._Sarcophagidae*	.	9.90	18	.	Beyer_et_al_1985
Pb	Pennsylvania	Palmerton	field	resident	predator	Insecta	Diptera	Sarcophagidae	*dip._Sarcophagidae*	.	41.00	24	.	Beyer_et_al_1985
Zn	Pennsylvania	Palmerton	field	resident	predator	Insecta	Diptera	Sarcophagidae	*dip._Sarcophagidae*	.	2900.00	460	.	Beyer_et_al_1985
Cd	Pennsylvania	Bake_Oven_Knob	field	resident	predator	Insecta	Coleoptera	Sylphidae	*carrion_beetles*	.	2.70	0.85	.	Beyer_et_al_1985
Cd	Pennsylvania	Palmerton	field	resident	predator	Insecta	Coleoptera	Sylphidae	*carrion_beetles*	.	35.00	1.3	.	Beyer_et_al_1985
Cu	Pennsylvania	Bake_Oven_Knob	field	resident	predator	Insecta	Coleoptera	Sylphidae	*carrion_beetles*	.	18.00	12	.	Beyer_et_al_1985
Cu	Pennsylvania	Palmerton	field	resident	predator	Insecta	Coleoptera	Sylphidae	*carrion_beetles*	.	9.90	13	.	Beyer_et_al_1985
Pb	Pennsylvania	Bake_Oven_Knob	field	resident	predator	Insecta	Coleoptera	Sylphidae	*carrion_beetles*	.	150.00	1.6	.	Beyer_et_al_1985
Pb	Pennsylvania	Palmerton	field	resident	predator	Insecta	Coleoptera	Sylphidae	*carrion_beetles*	.	41.00	2.5	.	Beyer_et_al_1985

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	*Species*	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Zn	Pennsylvania	Bake_Oven_Knob	field	resident	predator	Insecta	Coleoptera	Sylphidae	*carrion_beetles*	.	230.00	120	.	Beyer_et_al_1985
Zn	Pennsylvania	Palmerton	field	resident	predator	Insecta	Coleoptera	Sylphidae	*carrion_beetles*	.	2900.00	150	.	Beyer_et_al_1985
Cd	Pennsylvania	Bake_Oven_Knob	field	resident	predator	Insecta	Hymenoptera	Vespidae	*hornets*	.	2.70	2.3	.	Beyer_et_al_1985
Cu	Pennsylvania	Bake_Oven_Knob	field	resident	predator	Insecta	Hymenoptera	Vespidae	*hornets*	.	18.00	38	.	Beyer_et_al_1985
Pb	Pennsylvania	Bake_Oven_Knob	field	resident	predator	Insecta	Hymenoptera	Vespidae	*hornets*	.	150.00	2.1	.	Beyer_et_al_1985
Zn	Pennsylvania	Bake_Oven_Knob	field	resident	predator	Insecta	Hymenoptera	Vespidae	*hornets*	.	230.00	180	.	Beyer_et_al_1985
As	Pennsylvania	4	field	resident	detritivore	Diplipoda	.	Polydesmida	.	.	2.80	2.9	.	Beyer_et_al_1990
Cd	Pennsylvania	4	field	resident	detritivore	Diplipoda	.	Polydesmida	.	.	0.62	.	U	Beyer_et_al_1990
Cr	Pennsylvania	4	field	resident	detritivore	Diplipoda	.	Polydesmida	.	.	220.00	3.4	.	Beyer_et_al_1990
Cu	Pennsylvania	4	field	resident	detritivore	Diplipoda	.	Polydesmida	.	.	130.00	850	.	Beyer_et_al_1990
Pb	Pennsylvania	4	field	resident	detritivore	Diplipoda	.	Polydesmida	.	.	92.00	14	.	Beyer_et_al_1990
Ni	Pennsylvania	4	field	resident	detritivore	Diplipoda	.	Polydesmida	.	.	150.00	2.9	.	Beyer_et_al_1990
Se	Pennsylvania	4	field	resident	detritivore	Diplipoda	.	Polydesmida	.	.	0.75	.	U	Beyer_et_al_1990
Zn	Pennsylvania	4	field	resident	detritivore	Diplipoda	.	Polydesmida	.	.	240.00	650	.	Beyer_et_al_1990
As	Pennsylvania	4	field	resident	herbivore	Mollusca	slug	.	*Deroceras_laeve*	.	2.80	0.88	.	Beyer_et_al_1990
Cd	Pennsylvania	4	field	resident	herbivore	Mollusca	slug	.	*Deroceras_laeve*	.	0.62	.	U	Beyer_et_al_1990
Cr	Pennsylvania	4	field	resident	herbivore	Mollusca	slug	.	*Deroceras_laeve*	.	220.00	57	.	Beyer_et_al_1990
Cu	Pennsylvania	4	field	resident	herbivore	Mollusca	slug	.	*Deroceras_laeve*	.	130.00	180	.	Beyer_et_al_1990
Pb	Pennsylvania	4	field	resident	herbivore	Mollusca	slug	.	*Deroceras_laeve*	.	92.00	13	.	Beyer_et_al_1990
Ni	Pennsylvania	4	field	resident	herbivore	Mollusca	slug	.	*Deroceras_laeve*	.	150.00	47	.	Beyer_et_al_1990
Se	Pennsylvania	4	field	resident	herbivore	Mollusca	slug	.	*Deroceras_laeve*	.	0.75	.	U	Beyer_et_al_1990
Zn	Pennsylvania	4	field	resident	herbivore	Mollusca	slug	.	*Deroceras_laeve*	.	240.00	650	.	Beyer_et_al_1990
As	Delaware	2	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	10.00	.	U	Beyer_et_al_1990
As	Maryland	1	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	13.00	.	U	Beyer_et_al_1990
As	Maryland	3	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	7.80	.	U	Beyer_et_al_1990
As	Maryland	5	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	33.00	.	U	Beyer_et_al_1990
Cd	Delaware	2	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	1.50	.	U	Beyer_et_al_1990
Cd	Maryland	1	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	0.70	.	U	Beyer_et_al_1990
Cd	Maryland	3	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	1.00	.	U	Beyer_et_al_1990
Cd	Maryland	5	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	1.00	.	U	Beyer_et_al_1990
Cr	Delaware	2	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	20.00	12	.	Beyer_et_al_1990
Cr	Maryland	1	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	33.00	3.7	.	Beyer_et_al_1990
Cr	Maryland	3	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	26.00	2.2	.	Beyer_et_al_1990
Cr	Maryland	5	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	300.00	3	.	Beyer_et_al_1990
Cu	Delaware	2	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	15.00	14	.	Beyer_et_al_1990
Cu	Maryland	1	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	24.00	14	.	Beyer_et_al_1990
Cu	Maryland	3	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	71.00	17	.	Beyer_et_al_1990
Cu	Maryland	5	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	150.00	17	.	Beyer_et_al_1990
Pb	Delaware	2	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	22.00	0.86	.	Beyer_et_al_1990
Pb	Maryland	1	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	22.00	.	U	Beyer_et_al_1990
Pb	Maryland	3	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	29.00	.	U	Beyer_et_al_1990
Pb	Maryland	5	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	530.00	.	U	Beyer_et_al_1990
Ni	Delaware	2	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	17.00	8.7	.	Beyer_et_al_1990
Ni	Maryland	1	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	13.00	2.7	.	Beyer_et_al_1990
Ni	Maryland	3	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	12.00	1.4	.	Beyer_et_al_1990
Ni	Maryland	5	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	28.00	2.8	.	Beyer_et_al_1990
Se	Delaware	2	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	0.38	.	U	Beyer_et_al_1990
Se	Maryland	1	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	0.66	.	U	Beyer_et_al_1990
Se	Maryland	3	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	0.89	.	U	Beyer_et_al_1990
Se	Maryland	5	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	4.80	0.088	.	Beyer_et_al_1990
Zn	Delaware	2	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	120.00	160	.	Beyer_et_al_1990
Zn	Maryland	1	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	74.00	112	.	Beyer_et_al_1990
Zn	Maryland	3	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	83.00	104	.	Beyer_et_al_1990
Zn	Maryland	5	field	resident	predator	Insecta	Coleoptera	Coccinelidae	*C_septempunctata*	.	200.00	140	.	Beyer_et_al_1990

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	Species	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Cd	BritColumbia	red_clover_drained_field	field	resident	detritivore	Diplopoda	.	.	*millipedes*	.	0.40	0.2	.	Carter_1983
Cu	BritColumbia	red_clover_drained_field	field	resident	detritivore	Diplopoda	.	.	*millipedes*	.	26.00	221	.	Carter_1983
Zn	BritColumbia	red_clover_drained_field	field	resident	detritivore	Diplopoda	.	.	*millipedes*	.	83.00	321	.	Carter_1983
Cd	BritColumbia	red_clover_drained_field	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae_ad*	.	0.40	0.3	.	Carter_1983
Cu	BritColumbia	red_clover_drained_field	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae_ad*	.	26.00	13	.	Carter_1983
Zn	BritColumbia	red_clover_drained_field	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae_ad*	.	83.00	116	.	Carter_1983
Cd	BritColumbia	red_clover_drained_field	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinid_ad*	.	0.40	0.6	.	Carter_1983
Cu	BritColumbia	red_clover_drained_field	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinid_ad*	.	26.00	32	.	Carter_1983
Zn	BritColumbia	red_clover_drained_field	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinid_ad*	.	83.00	278	.	Carter_1983
Cd	Britain	control	lab	14days	herbivore	Insecta	Homoptera	Aphididae	*Aphis_fabae*	.	.	3.5	.	Crawford_et_al_1995
Cd	Britain	treatment	lab	14days	herbivore	Insecta	Homoptera	Aphididae	*Aphis_fabae*	.	.	29.1	.	Crawford_et_al_1995
Cu	Britain	control	lab	14days	herbivore	Insecta	Homoptera	Aphididae	*Aphis_fabae*	.	.	27.7	.	Crawford_et_al_1995
Cu	Britain	treatment	lab	14days	herbivore	Insecta	Homoptera	Aphididae	*Aphis_fabae*	.	.	31.3	.	Crawford_et_al_1995
Zn	Britain	control	lab	14days	herbivore	Insecta	Homoptera	Aphididae	*Aphis_fabae*	.	.	50.2	.	Crawford_et_al_1995
Zn	Britain	treatment	lab	14days	herbivore	Insecta	Homoptera	Aphididae	*Aphis_fabae*	.	.	153.2	.	Crawford_et_al_1995
Cd	Lab	2	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	2.00	.	.	Devkota_and_Schmidt_1999
Cd	Lab	2	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	2.00	.	.	Devkota_and_Schmidt_1999
Cd	Lab	2	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	2.00	.	.	Devkota_and_Schmidt_1999
Cd	Lab	2	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	2.00	.	.	Devkota_and_Schmidt_1999
Cd	Lab	10	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	10.00	.	.	Devkota_and_Schmidt_1999
Cd	Lab	10	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	10.00	.	.	Devkota_and_Schmidt_1999
Cd	Lab	10	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	10.00	.	.	Devkota_and_Schmidt_1999
Cd	Lab	10	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	10.00	.	.	Devkota_and_Schmidt_1999
Cd	Lab	20	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	20.00	.	.	Devkota_and_Schmidt_1999
Cd	Lab	20	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	20.00	.	.	Devkota_and_Schmidt_1999
Cd	Lab	20	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	20.00	.	.	Devkota_and_Schmidt_1999
Cd	Lab	20	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	20.00	.	.	Devkota_and_Schmidt_1999
Cd	Lab	50	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	50.00	.	.	Devkota_and_Schmidt_1999
Cd	Lab	50	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	50.00	.	.	Devkota_and_Schmidt_1999
Cd	Lab	50	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	50.00	.	.	Devkota_and_Schmidt_1999
Cd	Lab	50	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	50.00	.	.	Devkota_and_Schmidt_1999
Cd	Lab	100	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	100.00	.	.	Devkota_and_Schmidt_1999
Cd	Lab	100	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	100.00	.	.	Devkota_and_Schmidt_1999
Cd	Lab	100	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	100.00	.	.	Devkota_and_Schmidt_1999
Cd	Lab	100	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	100.00	.	.	Devkota_and_Schmidt_1999
Pb	Lab	25	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	25.00	.	.	Devkota_and_Schmidt_1999
Pb	Lab	25	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	25.00	.	.	Devkota_and_Schmidt_1999
Pb	Lab	25	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	25.00	.	.	Devkota_and_Schmidt_1999
Pb	Lab	25	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	25.00	.	.	Devkota_and_Schmidt_1999
Pb	Lab	50	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	50.00	.	.	Devkota_and_Schmidt_1999
Pb	Lab	50	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	50.00	.	.	Devkota_and_Schmidt_1999
Pb	Lab	50	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	50.00	.	.	Devkota_and_Schmidt_1999
Pb	Lab	50	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	50.00	.	.	Devkota_and_Schmidt_1999
Pb	Lab	100	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	100.00	.	.	Devkota_and_Schmidt_1999
Pb	Lab	100	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	100.00	.	.	Devkota_and_Schmidt_1999
Pb	Lab	100	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	100.00	.	.	Devkota_and_Schmidt_1999
Pb	Lab	100	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	100.00	.	.	Devkota_and_Schmidt_1999
Pb	Lab	250	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	250.00	.	.	Devkota_and_Schmidt_1999
Pb	Lab	250	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	250.00	.	.	Devkota_and_Schmidt_1999
Pb	Lab	250	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	250.00	.	.	Devkota_and_Schmidt_1999
Pb	Lab	250	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	250.00	.	.	Devkota_and_Schmidt_1999
Pb	Lab	500	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	500.00	.	.	Devkota_and_Schmidt_1999
Pb	Lab	500	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	500.00	.	.	Devkota_and_Schmidt_1999
Pb	Lab	500	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	500.00	.	.	Devkota_and_Schmidt_1999

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	*Species*	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Pb	Lab	500	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	500.00	.	.	Devkota_and_Schmidt_1999
Hg	Lab	0.121	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	0.121	.	.	Devkota_and_Schmidt_1999
Hg	Lab	0.121	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	0.121	.	.	Devkota_and_Schmidt_1999
Hg	Lab	0.121	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	0.121	.	.	Devkota_and_Schmidt_1999
Hg	Lab	0.121	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	0.121	.	.	Devkota_and_Schmidt_1999
Hg	Lab	0.605	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	0.605	.	.	Devkota_and_Schmidt_1999
Hg	Lab	0.605	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	0.605	.	.	Devkota_and_Schmidt_1999
Hg	Lab	0.605	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	0.605	.	.	Devkota_and_Schmidt_1999
Hg	Lab	1.21	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	1.21	.	.	Devkota_and_Schmidt_1999
Hg	Lab	1.21	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	1.21	.	.	Devkota_and_Schmidt_1999
Hg	Lab	1.21	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	1.210	.	.	Devkota_and_Schmidt_1999
Hg	Lab	6.05	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	6.05	.	.	Devkota_and_Schmidt_1999
Hg	Lab	6.05	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	6.05	.	.	Devkota_and_Schmidt_1999
Hg	Lab	12.1	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Eyprepocnemis_plorans*	.	12.10	.	.	Devkota_and_Schmidt_1999
Hg	Lab	12.1	lab	5weeks	herbivore	Insecta	Orthoptera	Acrididae	*Aiolopus_thalassinus*	.	12.10	.	.	Devkota_and_Schmidt_1999
Cd	Poland	Kuzie	field	resident	herbivore	Insecta	.	.	*herbivore_arthropods*	.	0.10	0.8	.	Dmowski_and_Karolewski_1979
Cd	Poland	pine_forest_	field	resident	herbivore	Insecta	.	.	*herbivore_arthropods*	.	7.80	11.3	.	Dmowski_and_Karolewski_1979
Cd	Poland	protection_zone	field	resident	herbivore	Insecta	.	.	*herbivore_arthropods*	.	4.10	10.3	.	Dmowski_and_Karolewski_1979
Pb	Poland	Kuzie	field	resident	herbivore	Insecta	.	.	*herbivore_arthropods*	.	3.00	1.4	.	Dmowski_and_Karolewski_1979
Pb	Poland	pine_forest_	field	resident	herbivore	Insecta	.	.	*herbivore_arthropods*	.	1377.80	497.6	.	Dmowski_and_Karolewski_1979
Pb	Poland	protection_zone	field	resident	herbivore	Insecta	.	.	*herbivore_arthropods*	.	869.60	108.9	.	Dmowski_and_Karolewski_1979
Zn	Poland	pine_forest_	field	resident	herbivore	Insecta	.	.	*herbivore_arthropods*	.	635.60	728.4	.	Dmowski_and_Karolewski_1979
Zn	Poland	protection_zone	field	resident	herbivore	Insecta	.	.	*herbivore_arthropods*	.	80.70	661.5	.	Dmowski_and_Karolewski_1979
Cd	Poland	Kuzie	field	resident	omnivore	Insecta	.	.	*omnivore_arthropods*	.	0.10	1.1	.	Dmowski_and_Karolewski_1979
Cd	Poland	pine_forest_	field	resident	omnivore	Insecta	.	.	*omnivore_arthropods*	.	7.80	23.9	.	Dmowski_and_Karolewski_1979
Cd	Poland	protection_zone	field	resident	omnivore	Insecta	.	.	*omnivore_arthropods*	.	4.10	15.3	.	Dmowski_and_Karolewski_1979
Pb	Poland	Kuzie	field	resident	omnivore	Insecta	.	.	*omnivore_arthropods*	.	3.00	2.3	.	Dmowski_and_Karolewski_1979
Pb	Poland	pine_forest_	field	resident	omnivore	Insecta	.	.	*omnivore_arthropods*	.	1377.80	487.2	.	Dmowski_and_Karolewski_1979
Pb	Poland	protection_zone	field	resident	omnivore	Insecta	.	.	*omnivore_arthropods*	.	869.60	362.6	.	Dmowski_and_Karolewski_1979
Zn	Poland	pine_forest_	field	resident	omnivore	Insecta	.	.	*omnivore_arthropods*	.	635.60	526.1	.	Dmowski_and_Karolewski_1979
Zn	Poland	protection_zone	field	resident	omnivore	Insecta	.	.	*omnivore_arthropods*	.	80.70	496.5	.	Dmowski_and_Karolewski_1979
Cd	Poland	Kuzie	field	resident	predator	Insecta	.	.	*predatory_arthropds*	.	0.10	2.4	.	Dmowski_and_Karolewski_1979
Cd	Poland	pine_forest_	field	resident	predator	Insecta	.	.	*predatory_arthropds*	.	7.80	33.5	.	Dmowski_and_Karolewski_1979
Cd	Poland	protection_zone	field	resident	predator	Insecta	.	.	*predatory_arthropds*	.	4.10	12.1	.	Dmowski_and_Karolewski_1979
Pb	Poland	Kuzie	field	resident	predator	Insecta	.	.	*predatory_arthropds*	.	3.00	0	.	Dmowski_and_Karolewski_1979
Pb	Poland	pine_forest_	field	resident	predator	Insecta	.	.	*predatory_arthropds*	.	1377.80	434.8	.	Dmowski_and_Karolewski_1979
Pb	Poland	protection_zone	field	resident	predator	Insecta	.	.	*predatory_arthropds*	.	869.60	346.3	.	Dmowski_and_Karolewski_1979
Zn	Poland	pine_forest_	field	resident	predator	Insecta	.	.	*predatory_arthropds*	.	635.60	1537.8	.	Dmowski_and_Karolewski_1979
Zn	Poland	protection_zone	field	resident	predator	Insecta	.	.	*predatory_arthropds*	.	80.70	789.6	.	Dmowski_and_Karolewski_1979
Cd	Netherlands	Bath	field	resident	herbivore	Insecta	Coleoptera	Cerambycidae	*A_villosoviridescens*	.	3.095	12.37	.	Hemminga_et_al_1989
Cd	Netherlands	Ellewoutsdijk	field	resident	herbivore	Insecta	Coleoptera	Cerambycidae	*A_villosoviridescens*	.	0.690	25.57	.	Hemminga_et_al_1989
Cd	Netherlands	Waarde	field	resident	herbivore	Insecta	Coleoptera	Cerambycidae	*A_villosoviridescens*	.	1.595	32.26	.	Hemminga_et_al_1989
Cu	Netherlands	Bath	field	resident	herbivore	Insecta	Coleoptera	Cerambycidae	*A_villosoviridescens*	.	35.20	54.95	.	Hemminga_et_al_1989
Cu	Netherlands	Ellewoutsdijk	field	resident	herbivore	Insecta	Coleoptera	Cerambycidae	*A_villosoviridescens*	.	21.30	47.82	.	Hemminga_et_al_1989
Cu	Netherlands	Waarde	field	resident	herbivore	Insecta	Coleoptera	Cerambycidae	*A_villosoviridescens*	.	27.80	51.37	.	Hemminga_et_al_1989
Ba	Virginia	.	field	resident	.	Insecta	.	.	beetles_and_termite_larva	.	104.20	16	.	Hope_et_al_1996
Cd	Britain	control	field	resident	herbivore	Insecta	Coleoptera	.	*herbivore_arthropods*	.	0.75	1.2	.	Hunter_and_Johnson_1982
Cd	Britain	intermediate	field	resident	herbivore	Insecta	Coleoptera	.	*herbivore_arthropods*	.	3.10	4.5	.	Hunter_and_Johnson_1982
Cd	Britain	refinery	field	resident	herbivore	Insecta	Coleoptera	.	*herbivore_arthropods*	.	8.50	10.9	.	Hunter_and_Johnson_1982
Cu	Britain	control	field	resident	herbivore	Insecta	Coleoptera	.	*herbivore_arthropods*	.	9.30	16.9	.	Hunter_and_Johnson_1982
Cu	Britain	intermediate	field	resident	herbivore	Insecta	Coleoptera	.	*herbivore_arthropods*	.	246.00	78.3	.	Hunter_and_Johnson_1982
Cu	Britain	refinery	field	resident	herbivore	Insecta	Coleoptera	.	*herbivore_arthropods*	.	2480.00	310	.	Hunter_and_Johnson_1982
Cd	Britain	control	field	resident	predator	Insecta	Coleoptera	.	*carnivore_arthropods*	.	0.75	2	.	Hunter_and_Johnson_1982
Cd	Britain	intermediate	field	resident	predator	Insecta	Coleoptera	.	*carnivore_arthropods*	.	3.10	6.9	.	Hunter_and_Johnson_1982

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	*Species*	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Cd	Britain	refinery	field	resident	predator	Insecta	Coleoptera	.	*carnivore_arthropods*	.	8.50	11.3	.	Hunter_and_Johnson_1982
Cu	Britain	control	field	resident	predator	Insecta	Coleoptera	.	*carnivore_arthropods*	.	9.30	22.7	.	Hunter_and_Johnson_1982
Cu	Britain	intermediate	field	resident	predator	Insecta	Coleoptera	.	*carnivore_arthropods*	.	246.00	86.4	.	Hunter_and_Johnson_1982
Cu	Britain	refinery	field	resident	predator	Insecta	Coleoptera	.	*carnivore_arthropods*	.	2480.00	568	.	Hunter_and_Johnson_1982
Cd	Britain	1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	*Chorthippus_brunneus*	.	.	1.63	.	Hunter_et_al_1987
Cd	Britain	2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	*Chorthippus_brunneus*	.	.	1.86	.	Hunter_et_al_1987
Cd	Britain	3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	*Chorthippus_brunneus*	.	.	2.1	.	Hunter_et_al_1987
Cd	Britain	4	field	resident	herbivore	Insecta	Orthoptera	Acrididae	*Chorthippus_brunneus*	.	.	2.44	.	Hunter_et_al_1987
Cd	Britain	1_km_site	field	resident	herbivore	Insecta	Orthoptera	Acrididae	*Chorthippus_brunneus*	.	.	1.24	.	Hunter_et_al_1987
Cd	Britain	control	field	resident	herbivore	Insecta	Orthoptera	Acrididae	*Chorthippus_brunneus*	.	.	0.19	.	Hunter_et_al_1987
Cu	Britain	1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	*Chorthippus_brunneus*	.	.	300	.	Hunter_et_al_1987
Cu	Britain	2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	*Chorthippus_brunneus*	.	.	349	.	Hunter_et_al_1987
Cu	Britain	3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	*Chorthippus_brunneus*	.	.	361	.	Hunter_et_al_1987
Cu	Britain	4	field	resident	herbivore	Insecta	Orthoptera	Acrididae	*Chorthippus_brunneus*	.	.	380	.	Hunter_et_al_1987
Cu	Britain	1_km_site	field	resident	herbivore	Insecta	Orthoptera	Acrididae	*Chorthippus_brunneus*	.	.	66.4	.	Hunter_et_al_1987
Cu	Britain	control	field	resident	herbivore	Insecta	Orthoptera	Acrididae	*Chorthippus_brunneus*	.	.	37.5	.	Hunter_et_al_1987
Pb	Lab	25	lab	7days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhornae*	.	.	596	.	Hussain_and_Jamil_1992
Pb	Lab	50	lab	7days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhornae*	.	.	468.2	.	Hussain_and_Jamil_1992
Pb	Lab	100	lab	7days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhornae*	.	.	551.6	.	Hussain_and_Jamil_1992
Hg	Lab	25	lab	7days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhornae*	.	.	196.5	.	Hussain_and_Jamil_1992
Hg	Lab	50	lab	7days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhornae*	.	.	137.1	.	Hussain_and_Jamil_1992
Hg	Lab	100	lab	7days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhornae*	.	.	106.2	.	Hussain_and_Jamil_1992
Cd	Lab	25	lab	7days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhornae*	.	.	525	.	Jamil_and_Hussain_1992
Cd	Lab	50	lab	7days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhornae*	.	.	456	.	Jamil_and_Hussain_1992
Cd	Lab	100	lab	7days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhornae*	.	.	526.7	.	Jamil_and_Hussain_1992
Mn	Lab	25	lab	7days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhornae*	.	.	120.6	.	Jamil_and_Hussain_1992
Mn	Lab	50	lab	7days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhornae*	.	.	181.6	.	Jamil_and_Hussain_1992
Mn	Lab	100	lab	7days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhornae*	.	.	241.7	.	Jamil_and_Hussain_1992
Hg	Lab	25	lab	7days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhornae*	.	.	147	.	Jamil_and_Hussain_1992
Hg	Lab	50	lab	7days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhornae*	.	.	131.8	.	Jamil_and_Hussain_1992
Hg	Lab	100	lab	7days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhornae*	.	.	110.5	.	Jamil_and_Hussain_1992
Zn	Lab	25	lab	7days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhornae*	.	.	634	.	Jamil_and_Hussain_1992
Zn	Lab	50	lab	7days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhornae*	.	.	408	.	Jamil_and_Hussain_1992
Zn	Lab	100	lab	7days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhornae*	.	.	356	.	Jamil_and_Hussain_1992
Pb	Netherlands	g	field	resident	detritivore	Insecta	Collembola	.	*Orchesella_cincta*	.	.	86	.	Joosse_and_Buker_1979
Pb	Netherlands	b_	lab	1day	detritivore	Insecta	Collembola	.	*Orchesella_cincta*	.	.	130	.	Joosse_and_Buker_1979
Pb	Netherlands	c_	lab	2days	detritivore	Insecta	Collembola	.	*Orchesella_cincta*	.	.	247	.	Joosse_and_Buker_1979
Pb	Netherlands	d	lab	1day	detritivore	Insecta	Collembola	.	*Orchesella_cincta*	.	.	50	.	Joosse_and_Buker_1979
Pb	Netherlands	e	lab	2days	detritivore	Insecta	Collembola	.	*Orchesella_cincta*	.	.	95	.	Joosse_and_Buker_1979
Pb	Netherlands	f	lab	14days	detritivore	Insecta	Collembola	.	*Orchesella_cincta*	.	.	360	.	Joosse_and_Buker_1979
Cd	Lab	1	lab	10days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhorniae*	.	.	14.46	.	Kay_and_Haller_1986
Cd	Lab	5	lab	10days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhorniae*	.	.	36.67	.	Kay_and_Haller_1986
Cd	Lab	control	lab	10days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhorniae*	.	.	6.52	.	Kay_and_Haller_1986
Cu	Lab	1	lab	10days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhorniae*	.	.	38.37	.	Kay_and_Haller_1986
Cu	Lab	5	lab	10days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhorniae*	.	.	32.77	.	Kay_and_Haller_1986
Cu	Lab	control	lab	10days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhorniae*	.	.	30.42	.	Kay_and_Haller_1986
Pb	Lab	1	lab	10days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhorniae*	.	.	0	.	Kay_and_Haller_1986
Pb	Lab	5	lab	10days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhorniae*	.	.	44.45	.	Kay_and_Haller_1986
Pb	Lab	control	lab	10days	herbivore	Insecta	Coleoptera	Curculionidae	*Neochetina_eichhorniae*	.	.	0	.	Kay_and_Haller_1986
Pb	Lab	1	lab	80days	detritivore	Isopoda	.	.	*P._Scaber*	.	.	1.66	.	Knigge_and_Kohler_2000
Pb	Lab	1	lab	80days	detritivore	Isopoda	.	.	*P._Scaber*	.	.	5.18	.	Knigge_and_Kohler_2000
Pb	Lab	10	lab	80days	detritivore	Isopoda	.	.	*P._Scaber*	.	.	13.9	.	Knigge_and_Kohler_2000
Pb	Lab	10	lab	80days	detritivore	Isopoda	.	.	*P._Scaber*	.	.	15.1	.	Knigge_and_Kohler_2000
Pb	Lab	100	lab	80days	detritivore	Isopoda	.	.	*P._Scaber*	.	.	389	.	Knigge_and_Kohler_2000

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	*Species*	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Pb	Lab	100	lab	80days	detritivore	Isopoda	.	.	*P._Scaber*	.	.	489	.	Knigge_and_Kohler_2000
Pb	Lab	control	lab	80days	detritivore	Isopoda	.	.	*P._Scaber*	.	.	1.93	.	Knigge_and_Kohler_2000
Pb	Lab	control	lab	80days	detritivore	Isopoda	.	.	*P._Scaber*	.	.	3.96	.	Knigge_and_Kohler_2000
Cd	Switzerland	low	field	resident	detritivore	Insecta	Coleoptera	.	*Geotrupes_stercorarious*	0.66	0.1	0.079	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	herbivore	Insecta	Coleoptera	.	*Rhagium_sycophanta_(larvae*	0.66	0.1	1.52	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	herbivore	Insecta	Coleoptera	.	*Phyllobius_arborator*	0.66	0.1	0.096	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	herbivore	Insecta	Coleoptera	.	*Rhagium_sycophanta_(pupae*	0.66	0.1	0.073	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	herbivore	Insecta	Coleoptera	.	*Strangalia_maculata*	0.66	0.1	0.316	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	herbivore	Insecta	Coleoptera	.	*Psylliodes_chrysocephala*	0.66	0.1	0.369	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	herbivore	Insecta	Coleoptera	.	*Phyllobius_sinuatus*	0.66	0.1	0.091	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	herbivore	Insecta	Coleoptera	.	*Pterostichus_oblongopuntatu*	0.66	0.1	0.092	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	herbivore	Insecta	Hemiptera	.	*Acanthosoma_haemorrhoidal*	0.66	0.1	0.175	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	herbivore	Insecta	Lepidoptera	.	*Scotia_exlamationis*	0.66	0.1	0.106	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	herbivore	Insecta	Lepidoptera	.	*Eilema_lurideiola_*	0.66	0.1	0.268	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	herbivore	Insecta	Lepidoptera	.	*Eilema_deplana*	0.66	0.1	0.177	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	herbivore	Insecta	Homoptera	Aphididae	*Aphididae*	0.66	0.1	0.012	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	herbivore	Insecta	Lepidoptera	Limacodidae	*Apoda_limacodes*	0.66	0.1	0.103	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	herbivore	Insecta	Hemiptera	Pentatomidae	*Pentatoma_rufipes*	0.66	0.1	0.311	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	herbivore	Insecta	Coleoptera	.	*Lagrea_hirta*	0.66	0.1	0.259	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	predator	Insecta	Coleoptera	.	*Amphimallon_solstitiale*	0.66	0.1	0.005	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	predator	Insecta	Coleoptera	Carabidae	*Abax_parallelepipedus*	0.66	0.1	0.288	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	predator	Insecta	Coleoptera	carabidae	*Molops_piceus*	0.66	0.1	0.286	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	predator	Insecta	Coleoptera	Carabidae	*Carabus_coriaceus*	0.66	0.1	0.416	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	predator	Insecta	Neuroptera	Chrysopidae	*Chrysopidae*	0.66	0.1	0.172	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	predator	Insecta	Coleoptera	Coccinellidae	*Calvia_decemguttata*	0.66	0.1	0.021	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Formica_fusca*	0.66	0.1	1.86	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	predator	Insecta	Hymenoptera	formicidae	*Myrmicinae*	0.66	0.1	0.189	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	predator	Insecta	Hymenoptera	formicidae	*Araschnia_levana_(larvae)*	0.66	0.1	0.018	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Formica_sanguinea*	0.66	0.1	1.85	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Formica_rufa*	0.66	0.1	1.07	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	predator	Insecta	Coleoptera	silphidae	*Necrophorus_vespilloides*	0.66	0.1	0.079	.	Knutti_et_al_1988
Cd	Switzerland	low	field	resident	predator	Insecta	Diptera	Syrphidae	*Syrphidae*	0.66	0.1	0.235	.	Knutti_et_al_1988
Cu	Lab	2	lab	4months	herbivore	Mollusca	snail	.	*Helix_aspersa*	.	.	134	.	Laskowski_and_Hopkin_1996
Cu	Lab	10	lab	4months	herbivore	Mollusca	snail	.	*Helix_aspersa*	.	.	285	.	Laskowski_and_Hopkin_1996
Cu	Lab	50	lab	4months	herbivore	Mollusca	snail	.	*Helix_aspersa*	.	.	223	.	Laskowski_and_Hopkin_1996
Cu	Lab	250	lab	4months	herbivore	Mollusca	snail	.	*Helix_aspersa*	.	.	703	.	Laskowski_and_Hopkin_1996
Cu	Lab	1250	lab	4months	herbivore	Mollusca	snail	.	*Helix_aspersa*	.	.	740	.	Laskowski_and_Hopkin_1996
Cu	Lab	control	lab	4months	herbivore	Mollusca	snail	.	*Helix_aspersa*	.	.	101	.	Laskowski_and_Hopkin_1996
Zn	Lab	20	lab	4months	herbivore	Mollusca	snail	.	*Helix_aspersa*	.	.	187	.	Laskowski_and_Hopkin_1996
Zn	Lab	100	lab	4months	herbivore	Mollusca	snail	.	*Helix_aspersa*	.	.	208	.	Laskowski_and_Hopkin_1996
Zn	Lab	500	lab	4months	herbivore	Mollusca	snail	.	*Helix_aspersa*	.	.	548	.	Laskowski_and_Hopkin_1996
Zn	Lab	2500	lab	4months	herbivore	Mollusca	snail	.	*Helix_aspersa*	.	.	1830	.	Laskowski_and_Hopkin_1996
Zn	Lab	12500	lab	4months	herbivore	Mollusca	snail	.	*Helix_aspersa*	.	.	1400	.	Laskowski_and_Hopkin_1996
Zn	Lab	control	lab	4months	herbivore	Mollusca	snail	.	*Helix_aspersa*	.	.	131	.	Laskowski_and_Hopkin_1996
Pb	Lab	control	lab	4months	herbivore	Mollusca	snail	.	*Helix_aspersa*	.	.	22	.	Laskowski_and_Hopkin_1996
Pb	Lab	20	lab	4months	herbivore	Mollusca	snail	.	*Helix_aspersa*	.	.	8	.	Laskowski_and_Hopkin_1996
Pb	Lab	100	lab	4months	herbivore	Mollusca	snail	.	*Helix_aspersa*	.	.	46	.	Laskowski_and_Hopkin_1996
Pb	Lab	500	lab	4months	herbivore	Mollusca	snail	.	*Helix_aspersa*	.	.	224	.	Laskowski_and_Hopkin_1996
Pb	Lab	2500	lab	4months	herbivore	Mollusca	snail	.	*Helix_aspersa*	.	.	640	.	Laskowski_and_Hopkin_1996
Pb	Lab	12500	lab	4months	herbivore	Mollusca	snail	.	*Helix_aspersa*	.	.	1240	.	Laskowski_and_Hopkin_1996
Cd	Lab	control	lab	4months	herbivore	Mollusca	snail	.	*Helix_aspersa*	.	.	7.3	.	Laskowski_and_Hopkin_1996
Cd	Lab	0.2	lab	4months	herbivore	Mollusca	snail	.	*Helix_aspersa*	.	.	2.9	.	Laskowski_and_Hopkin_1996
Cd	Lab	1	lab	4months	herbivore	Mollusca	snail	.	*Helix_aspersa*	.	.	7.5	.	Laskowski_and_Hopkin_1996
Cd	Lab	5	lab	4months	herbivore	Mollusca	snail	.	*Helix_aspersa*	.	.	18	.	Laskowski_and_Hopkin_1996

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	Species	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Cd	Lab	25	lab	4months	herbivore	Mollusca	snail	.	*Helix_aspersa*	.	.	55.3	.	Laskowski_and_Hopkin_1996
Cd	Lab	125	lab	4months	herbivore	Mollusca	snail	.	*Helix_aspersa*	.	.	154.5	.	Laskowski_and_Hopkin_1996
Cd	Sweden	Hallstavik	field	resident	herbivore	Insecta	Hymenoptera	Diprionidae	*Diprion_pini_(larvae)*	.	.	0.9	.	Lindqvist_1992
Cd	Sweden	Martsa	field	resident	herbivore	Insecta	Hymenoptera	Diprionidae	*Dolerus_nigratus_(larvae)*	.	.	0.7	.	Lindqvist_1992
Cu	Sweden	Hallstavik	field	resident	herbivore	Insecta	Hymenoptera	Diprionidae	*Diprion_pini_(larvae)*	.	.	10.4	.	Lindqvist_1992
Cu	Sweden	Martsa	field	resident	herbivore	Insecta	Hymenoptera	Diprionidae	*Dolerus_nigratus_(larvae)*	.	.	15.1	.	Lindqvist_1992
Zn	Sweden	Hallstavik	field	resident	herbivore	Insecta	Hymenoptera	Diprionidae	*Diprion_pini_(larvae)*	.	.	102	.	Lindqvist_1992
Zn	Sweden	Martsa	field	resident	herbivore	Insecta	Hymenoptera	Diprionidae	*Dolerus_nigratus_(larvae)*	.	.	137	.	Lindqvist_1992
Cd	Sweden	Martsa	field	resident	herbivore	Insecta	Lepidoptera	Nymphalidae	*Tortrix_viridana_(larvae)*	.	.	0.6	.	Lindqvist_1992
Cu	Sweden	Martsa	field	resident	herbivore	Insecta	Lepidoptera	Nymphalidae	*Tortrix_viridana_(larvae)*	.	.	8	.	Lindqvist_1992
Zn	Sweden	Martsa	field	resident	herbivore	Insecta	Lepidoptera	Nymphalidae	*Tortrix_viridana_(larvae)*	.	.	87	.	Lindqvist_1992
Cd	Sweden	Martsa	field	resident	herbivore	Insecta	Hymenoptera	Tenthedinidae	*Empria_baltica_(larvae)*	.	.	0.9	.	Lindqvist_1992
Cu	Sweden	Martsa	field	resident	herbivore	Insecta	Hymenoptera	Tenthedinidae	*Empria_baltica_(larvae)*	.	.	6.6	.	Lindqvist_1992
Zn	Sweden	Martsa	field	resident	herbivore	Insecta	Hymenoptera	Tenthedinidae	*Empria_baltica_(larvae)*	.	.	84	.	Lindqvist_1992
Cd	Sweden	Martsa	field	resident	herbivore	Insecta	Lepidoptera	Tortricidae	*Aglais_urticae_(larvae)*	.	.	0.9	.	Lindqvist_1992
Cu	Sweden	Martsa	field	resident	herbivore	Insecta	Lepidoptera	Tortricidae	*Aglais_urticae_(larvae)*	.	.	11.9	.	Lindqvist_1992
Zn	Sweden	Martsa	field	resident	herbivore	Insecta	Lepidoptera	Tortricidae	*Aglais_urticae_(larvae)*	.	.	119	.	Lindqvist_1992
Cd	Sweden	Martsa	field	resident	herbivore	Insecta	Hymenoptera	Diprionidae	*D._pini_(adult)*	.	.	0.4	.	Lindqvist_1992
Cu	Sweden	Hallstavik	field	resident	herbivore	Insecta	Hymenoptera	Diprionidae	*D._pini_(adult)*	.	.	46.5	.	Lindqvist_1992
Zn	Sweden	Hallstavik	field	resident	herbivore	Insecta	Hymenoptera	Diprionidae	*D._pini_(adult)*	.	.	273	.	Lindqvist_1992
Cd	Sweden	Martsa	field	resident	herbivore	Insecta	Lepidoptera	Nymphalidae	*A._urticae_(adult)*	.	.	0.3	.	Lindqvist_1992
Cu	Sweden	Martsa	field	resident	herbivore	Insecta	Lepidoptera	Nymphalidae	*A._urticae_(adult)*	.	.	16.6	.	Lindqvist_1992
Zn	Sweden	Martsa	field	resident	herbivore	Insecta	Lepidoptera	Nymphalidae	*A._urticae_(adult)*	.	.	159	.	Lindqvist_1992
Cd	Sweden	Martsa	field	resident	herbivore	Insecta	Hymenoptera	Tenthedinidae	*E._baltica_(adult)*	.	.	0.2	.	Lindqvist_1992
Cd	Sweden	Martsa	field	resident	herbivore	Insecta	Hymenoptera	Tenthedinidae	*D._nigratus_(adult)*	.	.	0.2	.	Lindqvist_1992
Cu	Sweden	Martsa	field	resident	herbivore	Insecta	Hymenoptera	Tenthedinidae	*E._baltica_(adult)*	.	.	25.8	.	Lindqvist_1992
Cu	Sweden	Martsa	field	resident	herbivore	Insecta	Hymenoptera	Tenthedinidae	*D._nigratus_(adult)*	.	.	41.5	.	Lindqvist_1992
Zn	Sweden	Martsa	field	resident	herbivore	Insecta	Hymenoptera	Tenthedinidae	*E._baltica_(adult)*	.	.	103	.	Lindqvist_1992
Zn	Sweden	Martsa	field	resident	herbivore	Insecta	Hymenoptera	Tenthedinidae	*D._nigratus_(adult)*	.	.	116	.	Lindqvist_1992
Cd	Sweden	Martsa	field	resident	herbivore	Insecta	Lepidoptera	Tortricidae	*T._viridana_(adult)*	.	.	0.4	.	Lindqvist_1992
Cu	Sweden	Martsa	field	resident	herbivore	Insecta	Lepidoptera	Tortricidae	*T._viridana_(adult)*	.	.	18.6	.	Lindqvist_1992
Zn	Sweden	Martsa	field	resident	herbivore	Insecta	Lepidoptera	Tortricidae	*T._viridana_(adult)*	.	.	173	.	Lindqvist_1992
Cd	Lab	0	lab	8weeks	detritivore	Isopoda	.	.	*Porcellio_larvis*	.	.	.	U	Odendaal_and_Reinecke_1999
Cd	Lab	10	lab	8weeks	detritivore	Isopoda	.	.	*Porcellio_larvis*	.	.	121.1	.	Odendaal_and_Reinecke_1999
Cd	Lab	20	lab	8weeks	detritivore	Isopoda	.	.	*Porcellio_larvis*	.	.	259	.	Odendaal_and_Reinecke_1999
Cd	Lab	40	lab	8weeks	detritivore	Isopoda	.	.	*Porcellio_larvis*	.	.	169.6	.	Odendaal_and_Reinecke_1999
Cd	Lab	80	lab	8weeks	detritivore	Isopoda	.	.	*Porcellio_larvis*	.	.	161.3	.	Odendaal_and_Reinecke_1999
PCB	Illinois	100	lab	14days	herbivore	Insecta	Orthoptera	Gryllidae	*Acheta_domesticus*	.	100.00	11.11	.	Paine_et_al_1993
PCB	Illinois	250	lab	14days	herbivore	Insecta	Orthoptera	Gryllidae	*Acheta_domesticus*	.	250.00	47.65	.	Paine_et_al_1993
PCB	Illinois	500	lab	14days	herbivore	Insecta	Orthoptera	Gryllidae	*Acheta_domesticus*	.	500.00	92.12	.	Paine_et_al_1993
PCB	Illinois	1000	lab	14days	herbivore	Insecta	Orthoptera	Gryllidae	*Acheta_domesticus*	.	1000.00	148.6	.	Paine_et_al_1993
PCB	Illinois	2000	lab	14days	herbivore	Insecta	Orthoptera	Gryllidae	*Acheta_domesticus*	.	2000.00	143.9	.	Paine_et_al_1993
PCB	Illinois	control	lab	14days	herbivore	Insecta	Orthoptera	Gryllidae	*Acheta_domesticus*	.	0.00	0.05	U	Paine_et_al_1993
As	Montana	milltown	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshoppers	.	67.10	3.9	.	Pascoe_et_al_1996
As	Montana	milltown_(reference)	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshoppers	.	7.70	0.02	U	Pascoe_et_al_1996
Cd	Montana	milltown	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshoppers	.	7.30	1.5	.	Pascoe_et_al_1996
Cd	Montana	milltown_(reference)	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshoppers	.	1.90	0.15	.	Pascoe_et_al_1996
Cu	Montana	milltown	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshoppers	.	584.70	60.5	.	Pascoe_et_al_1996
Cu	Montana	milltown_(reference)	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshoppers	.	17.90	0.036	U	Pascoe_et_al_1996
Zn	Montana	milltown	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshoppers	.	1949.50	270.8	.	Pascoe_et_al_1996
Zn	Montana	milltown_(reference)	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshoppers	.	49.30	80	.	Pascoe_et_al_1996
Cd	Belgium	Pl	field	resident	detritivore	Insecta	Collembola	.	*Orchesella_cincta*	2.90	27.50	0.58	.	Posthuma_1990
Cd	Germany	Br_	field	resident	detritivore	Insecta	Collembola	.	*Orchesella_cincta*	1.21	3.37	0.66	.	Posthuma_1990
Cd	Germany	St	field	resident	detritivore	Insecta	Collembola	.	*Orchesella_cincta*	5.30	62.60	1.95	.	Posthuma_1990

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	*Species*	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Cd	Netherlands	Bu	field	resident	detritivore	Insecta	Collembola	.	*Orchesella_cincta*	3.80	5.03	1.25	.	Posthuma_1990
Cd	Netherlands	Mo	field	resident	detritivore	Insecta	Collembola	.	*Orchesella_cincta*	1.03	1.12	0.4	.	Posthuma_1990
Cd	Netherlands	Ro	field	resident	detritivore	Insecta	Collembola	.	*Orchesella_cincta*	0.61	0.43	0.24	.	Posthuma_1990
Zn	Belgium	Pl	field	resident	detritivore	Insecta	Collembola	.	*Orchesella_cincta*	406.00	4915.40	113.2	.	Posthuma_1990
Zn	Germany	Br_	field	resident	detritivore	Insecta	Collembola	.	*Orchesella_cincta*	156.90	172.60	50	.	Posthuma_1990
Zn	Germany	St	field	resident	detritivore	Insecta	Collembola	.	*Orchesella_cincta*	331.50	1560.20	103.8	.	Posthuma_1990
Zn	Netherlands	Bu	field	resident	detritivore	Insecta	Collembola	.	*Orchesella_cincta*	906.30	949.50	121.9	.	Posthuma_1990
Zn	Netherlands	Mo	field	resident	detritivore	Insecta	Collembola	.	*Orchesella_cincta*	294.30	381.80	32.9	.	Posthuma_1990
Zn	Netherlands	Ro	field	resident	detritivore	Insecta	Collembola	.	*Orchesella_cincta*	34.70	32.70	34	.	Posthuma_1990
Cd	Lab	females-blank	lab	3days	detritivore	Insecta	Collembola	.	*Orchesella_cincta*	.	.	5.59	.	Posthuma_et_al_1992
Cd	Lab	females-chronic	lab	7weeks	detritivore	Insecta	Collembola	.	*Orchesella_cincta*	.	.	10.7	.	Posthuma_et_al_1992
Cd	Lab	males-blank	lab	3days	detritivore	Insecta	Collembola	.	*Orchesella_cincta*	.	.	5.7	.	Posthuma_et_al_1992
Cd	Lab	males-chronic	lab	7weeks	detritivore	Insecta	Collembola	.	*Orchesella_cincta*	.	.	12.12	.	Posthuma_et_al_1992
Pb	Illinois	ield_meadow_0-7_from_s	field	resident	herbivore	Insecta	.	.	*sucking_insects*	9.00	45.00	4.6	.	Price_et_al_1974
Pb	Illinois	ield_meadow_0-7_from_s	field	resident	herbivore	Insecta	.	.	*chewing_insects*	9.00	45.00	7.2	.	Price_et_al_1974
Pb	Illinois	I-74_0.7m_from_shoulder	field	resident	herbivore	Insecta	.	.	*sucking_insects*	25.00	60.00	15.7	.	Price_et_al_1974
Pb	Illinois	I-74_0.7m_from_shoulder	field	resident	herbivore	Insecta	.	.	*chewing_insects*	25.00	60.00	27.3	.	Price_et_al_1974
Pb	Illinois	4_13_-_20_m_from_shoul	field	resident	herbivore	Insecta	.	.	*sucking_insects*	15.00	20.00	9.8	.	Price_et_al_1974
Pb	Illinois	4_13_-_20_m_from_shoul	field	resident	herbivore	Insecta	.	.	*chewing_insects*	15.00	20.00	10.5	.	Price_et_al_1974
Pb	Illinois	lower_conc_areas	field	resident	herbivore	Insecta	.	.	*chewing_insects*	2.00	12.00	3.4	.	Price_et_al_1974
Pb	Illinois	lower_conc_areas	field	resident	herbivore	Insecta	.	.	*sucking_insects*	2.00	12.00	4.7	.	Price_et_al_1974
Pb	Illinois	ield_meadow_0-7_from_s	field	resident	predator	Insecta	.	.	*predatory_inscets*	9.00	45.00	22.8	.	Price_et_al_1974
Pb	Illinois	I-74_0.7m_from_shoulder	field	resident	predator	Insecta	.	.	*predatory_inscets*	25.00	60.00	31	.	Price_et_al_1974
Pb	Illinois	4_13_-_20_m_from_shoul	field	resident	predator	Insecta	.	.	*predatory_inscets*	15.00	20.00	20	.	Price_et_al_1974
Pb	Illinois	lower_conc_areas	field	resident	predator	Insecta	.	.	*predatory_inscets*	2.00	12.00	3.3	.	Price_et_al_1974
Al	Oklahoma	GRID1	field	resident	.	Insecta	Coleoptera	.	beetle	.	16400	106	.	PTI_1995
Al	Oklahoma	GRID4	field	resident	.	Insecta	Coleoptera	.	beetle	.	14550	40	.	PTI_1995
Al	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	16700	43	.	PTI_1995
Al	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	16700	426	.	PTI_1995
Al	Oklahoma	TRAP1	field	resident	.	Insecta	Coleoptera	.	beetle	.	16100	48	.	PTI_1995
Sb	Oklahoma	GRID1	field	resident	.	Insecta	Coleoptera	.	beetle	.	3	0.03	UJ	PTI_1995
Sb	Oklahoma	GRID4	field	resident	.	Insecta	Coleoptera	.	beetle	.	3.15	0.03	UJ	PTI_1995
Sb	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	3.2	0.03	UJ	PTI_1995
Sb	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	3.2	0.03	UJ	PTI_1995
Sb	Oklahoma	TRAP1	field	resident	.	Insecta	Coleoptera	.	beetle	.	3.5	0.02	UJ	PTI_1995
As	Oklahoma	GRID1	field	resident	.	Insecta	Coleoptera	.	beetle	.	5.7	0.5	.	PTI_1995
As	Oklahoma	GRID4	field	resident	.	Insecta	Coleoptera	.	beetle	.	17	0.5	.	PTI_1995
As	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	4.4	0.5	.	PTI_1995
As	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	4.4	0.5	.	PTI_1995
As	Oklahoma	TRAP1	field	resident	.	Insecta	Coleoptera	.	beetle	.	38.8	0.5	.	PTI_1995
Ba	Oklahoma	GRID1	field	resident	.	Insecta	Coleoptera	.	beetle	.	151	1.9	.	PTI_1995
Ba	Oklahoma	GRID4	field	resident	.	Insecta	Coleoptera	.	beetle	.	164	16.2	.	PTI_1995
Ba	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	131	4.6	.	PTI_1995
Ba	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	131	20.4	.	PTI_1995
Ba	Oklahoma	TRAP1	field	resident	.	Insecta	Coleoptera	.	beetle	.	176	19	.	PTI_1995
Be	Oklahoma	GRID1	field	resident	.	Insecta	Coleoptera	.	beetle	.	1.2	0.02	.	PTI_1995
Be	Oklahoma	GRID4	field	resident	.	Insecta	Coleoptera	.	beetle	.	0.95	0.02	.	PTI_1995
Be	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	1.4	0.02	.	PTI_1995
Be	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	1.4	0.02	.	PTI_1995
Be	Oklahoma	TRAP1	field	resident	.	Insecta	Coleoptera	.	beetle	.	1.3	0.02	.	PTI_1995
Cd	Oklahoma	GRID1	field	resident	.	Insecta	Coleoptera	.	beetle	.	26.6	4.3	J	PTI_1995
Cd	Oklahoma	GRID4	field	resident	.	Insecta	Coleoptera	.	beetle	.	33.1	1.7	J	PTI_1995
Cd	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	3.4	1.3	J	PTI_1995
Cd	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	3.4	3.2	J	PTI_1995

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	*Species*	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Cd	Oklahoma	TRAP1	field	resident	.	Insecta	Coleoptera	.	beetle	.	144	3.2	J	PTI_1995
Ca	Oklahoma	GRID1	field	resident	.	Insecta	Coleoptera	.	beetle	.	13000	1160	.	PTI_1995
Ca	Oklahoma	GRID4	field	resident	.	Insecta	Coleoptera	.	beetle	.	3715	1480	.	PTI_1995
Ca	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	2330	1410	.	PTI_1995
Ca	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	2330	1510	.	PTI_1995
Ca	Oklahoma	TRAP1	field	resident	.	Insecta	Coleoptera	.	beetle	.	8380	1470	.	PTI_1995
Cr	Oklahoma	GRID1	field	resident	.	Insecta	Coleoptera	.	beetle	.	27.3	2.2	.	PTI_1995
Cr	Oklahoma	GRID4	field	resident	.	Insecta	Coleoptera	.	beetle	.	26.45	2.8	.	PTI_1995
Cr	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	39.7	1.6	.	PTI_1995
Cr	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	39.7	6	.	PTI_1995
Cr	Oklahoma	TRAP1	field	resident	.	Insecta	Coleoptera	.	beetle	.	42.9	1.9	.	PTI_1995
Co	Oklahoma	GRID1	field	resident	.	Insecta	Coleoptera	.	beetle	.	15.6	0.15	.	PTI_1995
Co	Oklahoma	GRID4	field	resident	.	Insecta	Coleoptera	.	beetle	.	10.15	0.04	.	PTI_1995
Co	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	8.8	0.05	.	PTI_1995
Co	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	8.8	0.3	.	PTI_1995
Co	Oklahoma	TRAP1	field	resident	.	Insecta	Coleoptera	.	beetle	.	14.9	0.04	.	PTI_1995
Cu	Oklahoma	GRID1	field	resident	.	Insecta	Coleoptera	.	beetle	.	47.6	19	.	PTI_1995
Cu	Oklahoma	GRID4	field	resident	.	Insecta	Coleoptera	.	beetle	.	77.4	14	.	PTI_1995
Cu	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	21.9	15	.	PTI_1995
Cu	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	21.9	19	.	PTI_1995
Cu	Oklahoma	TRAP1	field	resident	.	Insecta	Coleoptera	.	beetle	.	186	15	.	PTI_1995
Fe	Oklahoma	GRID1	field	resident	.	Insecta	Coleoptera	.	beetle	.	26100	166	.	PTI_1995
Fe	Oklahoma	GRID4	field	resident	.	Insecta	Coleoptera	.	beetle	.	20450	141	.	PTI_1995
Fe	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	32800	118	.	PTI_1995
Fe	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	32800	436	.	PTI_1995
Fe	Oklahoma	TRAP1	field	resident	.	Insecta	Coleoptera	.	beetle	.	27000	114	.	PTI_1995
Pb	Oklahoma	GRID1	field	resident	.	Insecta	Coleoptera	.	beetle	.	83.9	2.9	.	PTI_1995
Pb	Oklahoma	GRID4	field	resident	.	Insecta	Coleoptera	.	beetle	.	281.5	0.63	.	PTI_1995
Pb	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	55.6	0.4	.	PTI_1995
Pb	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	55.6	1.1	.	PTI_1995
Pb	Oklahoma	TRAP1	field	resident	.	Insecta	Coleoptera	.	beetle	.	485	1.6	.	PTI_1995
Mg	Oklahoma	GRID1	field	resident	.	Insecta	Coleoptera	.	beetle	.	2850	1170	.	PTI_1995
Mg	Oklahoma	GRID4	field	resident	.	Insecta	Coleoptera	.	beetle	.	2120	1740	.	PTI_1995
Mg	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	2170	1490	.	PTI_1995
Mg	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	2170	1770	.	PTI_1995
Mg	Oklahoma	TRAP1	field	resident	.	Insecta	Coleoptera	.	beetle	.	2530	1760	.	PTI_1995
Mn	Oklahoma	GRID1	field	resident	.	Insecta	Coleoptera	.	beetle	.	486	22.6	.	PTI_1995
Mn	Oklahoma	GRID4	field	resident	.	Insecta	Coleoptera	.	beetle	.	583	36.7	.	PTI_1995
Mn	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	285	38	.	PTI_1995
Mn	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	285	42.6	.	PTI_1995
Mn	Oklahoma	TRAP1	field	resident	.	Insecta	Coleoptera	.	beetle	.	615	35.7	.	PTI_1995
Hg	Oklahoma	GRID1	field	resident	.	Insecta	Coleoptera	.	beetle	.	0.09	0.05	.	PTI_1995
Hg	Oklahoma	GRID4	field	resident	.	Insecta	Coleoptera	.	beetle	.	0.09	0.05	.	PTI_1995
Hg	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	0.05	0.05	.	PTI_1995
Hg	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	0.05	0.1	.	PTI_1995
Hg	Oklahoma	TRAP1	field	resident	.	Insecta	Coleoptera	.	beetle	.	0.86	0.05	.	PTI_1995
Ni	Oklahoma	GRID1	field	resident	.	Insecta	Coleoptera	.	beetle	.	26	2	.	PTI_1995
Ni	Oklahoma	GRID4	field	resident	.	Insecta	Coleoptera	.	beetle	.	19.15	2	.	PTI_1995
Ni	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	15.1	2	.	PTI_1995
Ni	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	15.1	3	.	PTI_1995
Ni	Oklahoma	TRAP1	field	resident	.	Insecta	Coleoptera	.	beetle	.	27.9	2	.	PTI_1995
K	Oklahoma	GRID1	field	resident	.	Insecta	Coleoptera	.	beetle	.	1400	6070	.	PTI_1995
K	Oklahoma	GRID4	field	resident	.	Insecta	Coleoptera	.	beetle	.	2325	10100	.	PTI_1995
K	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	2000	6900	.	PTI_1995

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	*Species*	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
K	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	2000	10200	.	PTI_1995
K	Oklahoma	TRAP1	field	resident	.	Insecta	Coleoptera	.	beetle	.	1980	10200	.	PTI_1995
Se	Oklahoma	GRID1	field	resident	.	Insecta	Coleoptera	.	beetle	.	0.2	1	U	PTI_1995
Se	Oklahoma	GRID4	field	resident	.	Insecta	Coleoptera	.	beetle	.	0.62	1	.	PTI_1995
Se	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	0.3	1	U	PTI_1995
Se	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	0.3	1	U	PTI_1995
Se	Oklahoma	TRAP1	field	resident	.	Insecta	Coleoptera	.	beetle	.	19.2	1	.	PTI_1995
Ag	Oklahoma	GRID1	field	resident	.	Insecta	Coleoptera	.	beetle	.	1	0.06	J	PTI_1995
Ag	Oklahoma	GRID4	field	resident	.	Insecta	Coleoptera	.	beetle	.	2.9	0.02	J	PTI_1995
Ag	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	1.2	0.03	J	PTI_1995
Ag	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	1.2	0.03	J	PTI_1995
Ag	Oklahoma	TRAP1	field	resident	.	Insecta	Coleoptera	.	beetle	.	5.4	0.04	J	PTI_1995
Na	Oklahoma	GRID1	field	resident	.	Insecta	Coleoptera	.	beetle	.	148	1230	.	PTI_1995
Na	Oklahoma	GRID4	field	resident	.	Insecta	Coleoptera	.	beetle	.	61.4	1530	.	PTI_1995
Na	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	67.6	1180	.	PTI_1995
Na	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	67.6	1790	.	PTI_1995
Na	Oklahoma	TRAP1	field	resident	.	Insecta	Coleoptera	.	beetle	.	395	1600	.	PTI_1995
Tl	Oklahoma	GRID1	field	resident	.	Insecta	Coleoptera	.	beetle	.	0.36	0.02	J	PTI_1995
Tl	Oklahoma	GRID4	field	resident	.	Insecta	Coleoptera	.	beetle	.	0.33	0.02	J	PTI_1995
Tl	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	0.38	0.02	J	PTI_1995
Tl	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	0.38	0.02	J	PTI_1995
Tl	Oklahoma	TRAP1	field	resident	.	Insecta	Coleoptera	.	beetle	.	1.4	0.02	UJ	PTI_1995
V	Oklahoma	GRID1	field	resident	.	Insecta	Coleoptera	.	beetle	.	30.7	0.3	.	PTI_1995
V	Oklahoma	GRID4	field	resident	.	Insecta	Coleoptera	.	beetle	.	30.85	0.2	.	PTI_1995
V	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	44.5	0.2	.	PTI_1995
V	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	44.5	0.8	.	PTI_1995
V	Oklahoma	TRAP1	field	resident	.	Insecta	Coleoptera	.	beetle	.	57.9	0.2	.	PTI_1995
Zn	Oklahoma	GRID1	field	resident	.	Insecta	Coleoptera	.	beetle	.	3210	266	.	PTI_1995
Zn	Oklahoma	GRID4	field	resident	.	Insecta	Coleoptera	.	beetle	.	2135	150	.	PTI_1995
Zn	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	413	136	.	PTI_1995
Zn	Oklahoma	TERB	field	resident	.	Insecta	Coleoptera	.	beetle	.	413	281	.	PTI_1995
Zn	Oklahoma	TRAP1	field	resident	.	Insecta	Coleoptera	.	beetle	.	7170	180	.	PTI_1995
Al	Oklahoma	GRID1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	16400	444	.	PTI_1995
Al	Oklahoma	GRID2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	14700	52	.	PTI_1995
Al	Oklahoma	GRID4	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	14550	44	.	PTI_1995
Al	Oklahoma	TERA	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	12700	46	.	PTI_1995
Al	Oklahoma	TERC	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	17800	125	.	PTI_1995
Al	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	16100	46	.	PTI_1995
Al	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	13600	31	.	PTI_1995
Sb	Oklahoma	GRID1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	3	0.05	UJ	PTI_1995
Sb	Oklahoma	GRID2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	3.4	0.1	UJ	PTI_1995
Sb	Oklahoma	GRID4	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	3.15	0.02	UJ	PTI_1995
Sb	Oklahoma	TERA	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	4	0.1	J	PTI_1995
Sb	Oklahoma	TERC	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	4.1	0.03	J	PTI_1995
Sb	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	3.5	0.03	UJ	PTI_1995
Sb	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	3.1	0.06	UJ	PTI_1995
As	Oklahoma	GRID1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	5.7	0.5	.	PTI_1995
As	Oklahoma	GRID2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	20.8	1	.	PTI_1995
As	Oklahoma	GRID4	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	17	0.5	.	PTI_1995
As	Oklahoma	TERA	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	2.9	1	.	PTI_1995
As	Oklahoma	TERC	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	6.3	0.5	.	PTI_1995
As	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	38.8	0.5	.	PTI_1995
As	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	7.9	0.5	.	PTI_1995
Ba	Oklahoma	GRID1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	151	12.9	.	PTI_1995

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	*Species*	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Ba	Oklahoma	GRID2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	160	21.7	.	PTI_1995
Ba	Oklahoma	GRID4	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	164	9.9	.	PTI_1995
Ba	Oklahoma	TERA	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	98.2	29.7	.	PTI_1995
Ba	Oklahoma	TERC	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	222	6.8	.	PTI_1995
Ba	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	176	10.4	.	PTI_1995
Ba	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	157	8.8	.	PTI_1995
Be	Oklahoma	GRID1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	1.2	0.02	.	PTI_1995
Be	Oklahoma	GRID2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.95	0.1	.	PTI_1995
Be	Oklahoma	GRID4	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.95	0.02	.	PTI_1995
Be	Oklahoma	TERA	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.7	0.1	.	PTI_1995
Be	Oklahoma	TERC	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	1.2	0.02	.	PTI_1995
Be	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	1.3	0.02	.	PTI_1995
Be	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.87	0.02	.	PTI_1995
Cd	Oklahoma	GRID1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	26.6	6.5	J	PTI_1995
Cd	Oklahoma	GRID2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	69.8	8	J	PTI_1995
Cd	Oklahoma	GRID4	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	33.1	12.5	J	PTI_1995
Cd	Oklahoma	TERA	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.89	1	J	PTI_1995
Cd	Oklahoma	TERC	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.6	0.19	U	PTI_1995
Cd	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	144	16.5	J	PTI_1995
Cd	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	36	10.6	J	PTI_1995
Ca	Oklahoma	GRID1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	13000	4840	.	PTI_1995
Ca	Oklahoma	GRID2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	2500	3560	.	PTI_1995
Ca	Oklahoma	GRID4	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	3715	2540	.	PTI_1995
Ca	Oklahoma	TERA	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	1670	1860	.	PTI_1995
Ca	Oklahoma	TERC	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	66200	3280	.	PTI_1995
Ca	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	8380	4420	.	PTI_1995
Ca	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	4110	2600	.	PTI_1995
Cr	Oklahoma	GRID1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	27.3	14.9	.	PTI_1995
Cr	Oklahoma	GRID2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	24.7	13	.	PTI_1995
Cr	Oklahoma	GRID4	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	26.45	1.7	.	PTI_1995
Cr	Oklahoma	TERA	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	24.3	18	.	PTI_1995
Cr	Oklahoma	TERC	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	33.4	2	.	PTI_1995
Cr	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	42.9	1.7	.	PTI_1995
Cr	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	25.2	3.9	.	PTI_1995
Co	Oklahoma	GRID1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	15.6	0.3	.	PTI_1995
Co	Oklahoma	GRID2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	9.2	0.1	.	PTI_1995
Co	Oklahoma	GRID4	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	10.15	0.04	.	PTI_1995
Co	Oklahoma	TERA	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	6.4	0.2	.	PTI_1995
Co	Oklahoma	TERC	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	13	0.07	.	PTI_1995
Co	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	14.9	0.06	.	PTI_1995
Co	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	9.6	0.07	.	PTI_1995
Cu	Oklahoma	GRID1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	47.6	18	.	PTI_1995
Cu	Oklahoma	GRID2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	180	22	.	PTI_1995
Cu	Oklahoma	GRID4	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	77.4	15	.	PTI_1995
Cu	Oklahoma	TERA	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	11.4	17	.	PTI_1995
Cu	Oklahoma	TERC	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	20.3	11	.	PTI_1995
Cu	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	186	16	.	PTI_1995
Cu	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	63.7	17	.	PTI_1995
Fe	Oklahoma	GRID1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	26100	907	.	PTI_1995
Fe	Oklahoma	GRID2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	19800	457	.	PTI_1995
Fe	Oklahoma	GRID4	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	20450	103	.	PTI_1995
Fe	Oklahoma	TERA	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	16800	770	.	PTI_1995
Fe	Oklahoma	TERC	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	28200	136	.	PTI_1995
Fe	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	27000	112	.	PTI_1995

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	*Species*	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Fe	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	19300	139	.	PTI_1995
Pb	Oklahoma	GRID1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	83.9	11.9	.	PTI_1995
Pb	Oklahoma	GRID2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	435	1.6	.	PTI_1995
Pb	Oklahoma	GRID4	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	281.5	0.42	.	PTI_1995
Pb	Oklahoma	TERA	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	26.7	0.4	.	PTI_1995
Pb	Oklahoma	TERC	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	26.5	0.22	.	PTI_1995
Pb	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	485	0.94	.	PTI_1995
Pb	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	179	0.69	.	PTI_1995
Mg	Oklahoma	GRID1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	2850	2870	.	PTI_1995
Mg	Oklahoma	GRID2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	1750	2700	.	PTI_1995
Mg	Oklahoma	GRID4	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	2120	3170	.	PTI_1995
Mg	Oklahoma	TERA	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	1450	2540	.	PTI_1995
Mg	Oklahoma	TERC	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	3400	1900	.	PTI_1995
Mg	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	2530	2760	.	PTI_1995
Mg	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	2140	3220	.	PTI_1995
Mn	Oklahoma	GRID1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	486	27.6	.	PTI_1995
Mn	Oklahoma	GRID2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	578	18	.	PTI_1995
Mn	Oklahoma	GRID4	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	583	34.7	.	PTI_1995
Mn	Oklahoma	TERA	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	150	34	.	PTI_1995
Mn	Oklahoma	TERC	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	1260	51.2	.	PTI_1995
Mn	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	615	31.6	.	PTI_1995
Mn	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	524	36.9	.	PTI_1995
Hg	Oklahoma	GRID1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.09	0.08	.	PTI_1995
Hg	Oklahoma	GRID2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.19	0.2	.	PTI_1995
Hg	Oklahoma	GRID4	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.09	0.05	.	PTI_1995
Hg	Oklahoma	TERA	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.03	0.2	.	PTI_1995
Hg	Oklahoma	TERC	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.06	0.05	.	PTI_1995
Hg	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.86	0.05	.	PTI_1995
Hg	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.08	0.05	.	PTI_1995
Ni	Oklahoma	GRID1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	26	2	.	PTI_1995
Ni	Oklahoma	GRID2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	17.5	10	.	PTI_1995
Ni	Oklahoma	GRID4	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	19.15	2	.	PTI_1995
Ni	Oklahoma	TERA	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	9.9	10	.	PTI_1995
Ni	Oklahoma	TERC	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	36.4	2	.	PTI_1995
Ni	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	27.9	2	.	PTI_1995
Ni	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	20.2	2	.	PTI_1995
K	Oklahoma	GRID1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	1400	21300	.	PTI_1995
K	Oklahoma	GRID2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	1850	27400	.	PTI_1995
K	Oklahoma	GRID4	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	2325	25300	.	PTI_1995
K	Oklahoma	TERA	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	1440	18700	.	PTI_1995
K	Oklahoma	TERC	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	3040	23200	.	PTI_1995
K	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	1980	22000	.	PTI_1995
K	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	2320	27300	.	PTI_1995
Se	Oklahoma	GRID1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.2	1	U	PTI_1995
Se	Oklahoma	GRID2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.94	4	.	PTI_1995
Se	Oklahoma	GRID4	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.62	1	.	PTI_1995
Se	Oklahoma	TERA	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.3	4	U	PTI_1995
Se	Oklahoma	TERC	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.33	1	J	PTI_1995
Se	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	19.2	6	.	PTI_1995
Se	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.57	1	.	PTI_1995
Ag	Oklahoma	GRID1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	1	0.12	J	PTI_1995
Ag	Oklahoma	GRID2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	6.9	0.1	J	PTI_1995
Ag	Oklahoma	GRID4	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	2.9	0.03	J	PTI_1995
Ag	Oklahoma	TERA	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.59	0.1	J	PTI_1995

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	*Species*	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Ag	Oklahoma	TERC	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.5	0.02	UJ	PTI_1995
Ag	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	5.4	0.02	J	PTI_1995
Ag	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	2.1	0.02	J	PTI_1995
Na	Oklahoma	GRID1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	148	191	.	PTI_1995
Na	Oklahoma	GRID2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	49.3	533	.	PTI_1995
Na	Oklahoma	GRID4	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	61.4	91	.	PTI_1995
Na	Oklahoma	TERA	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	40.6	116	.	PTI_1995
Na	Oklahoma	TERC	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	78.1	106	.	PTI_1995
Na	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	395	304	.	PTI_1995
Na	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	57.3	176	.	PTI_1995
Tl	Oklahoma	GRID1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.36	0.02	J	PTI_1995
Tl	Oklahoma	GRID2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.38	0.1	J	PTI_1995
Tl	Oklahoma	GRID4	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.33	0.02	J	PTI_1995
Tl	Oklahoma	TERA	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.39	0.1	J	PTI_1995
Tl	Oklahoma	TERC	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	1.4	0.02	UJ	PTI_1995
Tl	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	1.4	0.02	UJ	PTI_1995
Tl	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	0.37	0.02	J	PTI_1995
V	Oklahoma	GRID1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	30.7	1.1	.	PTI_1995
V	Oklahoma	GRID2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	30.4	0.5	.	PTI_1995
V	Oklahoma	GRID4	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	30.85	0.2	.	PTI_1995
V	Oklahoma	TERA	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	24.8	0.5	.	PTI_1995
V	Oklahoma	TERC	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	33.7	0.4	.	PTI_1995
V	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	57.9	0.2	.	PTI_1995
V	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	28.4	0.2	.	PTI_1995
Zn	Oklahoma	GRID1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	3210	478	.	PTI_1995
Zn	Oklahoma	GRID2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	3750	744	.	PTI_1995
Zn	Oklahoma	GRID4	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	2135	407	.	PTI_1995
Zn	Oklahoma	TERA	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	154	229	.	PTI_1995
Zn	Oklahoma	TERC	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	169	102	.	PTI_1995
Zn	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	7170	593	.	PTI_1995
Zn	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Lepidoptera	.	catapillar	.	2270	366	.	PTI_1995
Al	Oklahoma	GRID1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	16400	182	.	PTI_1995
Al	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	14700	18	.	PTI_1995
Al	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	14700	24	.	PTI_1995
Al	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	12200	23	.	PTI_1995
Al	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	12200	30	.	PTI_1995
Al	Oklahoma	GRID4	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	14550	12	.	PTI_1995
Al	Oklahoma	TERA	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	12700	25	.	PTI_1995
Al	Oklahoma	TERB	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	16700	12.5	.	PTI_1995
Al	Oklahoma	TERC	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	17800	73	.	PTI_1995
Al	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	16100	14	.	PTI_1995
Al	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	16100	29	.	PTI_1995
Al	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	13600	19	.	PTI_1995
Sb	Oklahoma	GRID1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	3	0.03	UJ	PTI_1995
Sb	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	3.4	0.03	UJ	PTI_1995
Sb	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	3.4	0.03	UJ	PTI_1995
Sb	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	4.4	0.02	J	PTI_1995
Sb	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	4.4	0.02	J	PTI_1995
Sb	Oklahoma	GRID4	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	3.15	0.04	UJ	PTI_1995
Sb	Oklahoma	TERA	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	4	0.03	J	PTI_1995
Sb	Oklahoma	TERB	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	3.2	0.03	UJ	PTI_1995
Sb	Oklahoma	TERC	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	4.1	0.03	J	PTI_1995
Sb	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	3.5	0.03	UJ	PTI_1995
Sb	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	3.5	0.03	UJ	PTI_1995

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	*Species*	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Sb	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	3.1	0.04	UJ	PTI_1995
As	Oklahoma	GRID1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	5.7	0.5	.	PTI_1995
As	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	20.8	0.5	.	PTI_1995
As	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	20.8	0.5	.	PTI_1995
As	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	15.4	0.5	.	PTI_1995
As	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	15.4	0.5	.	PTI_1995
As	Oklahoma	GRID4	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	17	0.5	.	PTI_1995
As	Oklahoma	TERA	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	2.9	0.5	.	PTI_1995
As	Oklahoma	TERB	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	4.4	0.5	.	PTI_1995
As	Oklahoma	TERC	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	6.3	0.5	.	PTI_1995
As	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	38.8	0.5	.	PTI_1995
As	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	38.8	0.5	.	PTI_1995
As	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	7.9	0.5	.	PTI_1995
Ba	Oklahoma	GRID1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	151	3.6	.	PTI_1995
Ba	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	160	2.8	.	PTI_1995
Ba	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	160	2.9	.	PTI_1995
Ba	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	92.2	2.5	.	PTI_1995
Ba	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	92.2	2.9	.	PTI_1995
Ba	Oklahoma	GRID4	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	164	2.9	.	PTI_1995
Ba	Oklahoma	TERA	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	98.2	5.1	.	PTI_1995
Ba	Oklahoma	TERB	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	131	4.7	.	PTI_1995
Ba	Oklahoma	TERC	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	222	2.9	.	PTI_1995
Ba	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	176	2.8	.	PTI_1995
Ba	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	176	3.8	.	PTI_1995
Ba	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	157	3.4	.	PTI_1995
Be	Oklahoma	GRID1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	1.2	0.02	.	PTI_1995
Be	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.95	0.02	.	PTI_1995
Be	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.95	0.02	.	PTI_1995
Be	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.84	0.02	.	PTI_1995
Be	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.84	0.02	.	PTI_1995
Be	Oklahoma	GRID4	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.95	0.02	.	PTI_1995
Be	Oklahoma	TERA	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.7	0.02	.	PTI_1995
Be	Oklahoma	TERB	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	1.4	0.02	.	PTI_1995
Be	Oklahoma	TERC	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	1.2	0.02	.	PTI_1995
Be	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	1.3	0.02	.	PTI_1995
Be	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	1.3	0.02	.	PTI_1995
Be	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.87	0.02	.	PTI_1995
Cd	Oklahoma	GRID1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	26.6	4.8	J	PTI_1995
Cd	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	69.8	4.9	J	PTI_1995
Cd	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	69.8	5.7	J	PTI_1995
Cd	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	25.2	4.2	J	PTI_1995
Cd	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	25.2	4.5	J	PTI_1995
Cd	Oklahoma	GRID4	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	33.1	5	J	PTI_1995
Cd	Oklahoma	TERA	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.89	0.7	J	PTI_1995
Cd	Oklahoma	TERB	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	3.4	5.2	J	PTI_1995
Cd	Oklahoma	TERC	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.6	0.23	U	PTI_1995
Cd	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	144	5.8	J	PTI_1995
Cd	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	144	6.4	J	PTI_1995
Cd	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	36	3.1	J	PTI_1995
Ca	Oklahoma	GRID1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	13000	1930	.	PTI_1995
Ca	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	2500	908	.	PTI_1995
Ca	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	2500	1090	.	PTI_1995
Ca	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	1790	973	.	PTI_1995
Ca	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	1790	1050	.	PTI_1995

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	*Species*	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Ca	Oklahoma	GRID4	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	3715	1400	.	PTI_1995
Ca	Oklahoma	TERA	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	1670	1130	.	PTI_1995
Ca	Oklahoma	TERB	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	2330	2000	.	PTI_1995
Ca	Oklahoma	TERC	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	66200	1750	.	PTI_1995
Ca	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	8380	1460	.	PTI_1995
Ca	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	8380	1480	.	PTI_1995
Ca	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	4110	1190	.	PTI_1995
Cr	Oklahoma	GRID1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	27.3	2.4	.	PTI_1995
Cr	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	24.7	1.2	.	PTI_1995
Cr	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	24.7	1.3	.	PTI_1995
Cr	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	21.4	1.2	.	PTI_1995
Cr	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	21.4	1.7	.	PTI_1995
Cr	Oklahoma	GRID4	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	26.45	1	.	PTI_1995
Cr	Oklahoma	TERA	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	24.3	3.5	.	PTI_1995
Cr	Oklahoma	TERB	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	39.7	1.3	.	PTI_1995
Cr	Oklahoma	TERC	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	33.4	2.2	.	PTI_1995
Cr	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	42.9	1.1	.	PTI_1995
Cr	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	42.9	1.5	.	PTI_1995
Cr	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	25.2	0.5	.	PTI_1995
Co	Oklahoma	GRID1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	15.6	0.17	.	PTI_1995
Co	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	9.2	0.03	.	PTI_1995
Co	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	9.2	0.03	.	PTI_1995
Co	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	8.3	0.03	.	PTI_1995
Co	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	8.3	0.05	.	PTI_1995
Co	Oklahoma	GRID4	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	10.15	0.04	.	PTI_1995
Co	Oklahoma	TERA	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	6.4	0.13	.	PTI_1995
Co	Oklahoma	TERB	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	8.8	0.2	.	PTI_1995
Co	Oklahoma	TERC	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	13	0.06	.	PTI_1995
Co	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	14.9	0.05	.	PTI_1995
Co	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	14.9	0.11	.	PTI_1995
Co	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	9.6	0.06	.	PTI_1995
Cu	Oklahoma	GRID1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	47.6	72	.	PTI_1995
Cu	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	180	45	.	PTI_1995
Cu	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	180	52	.	PTI_1995
Cu	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	68	37	.	PTI_1995
Cu	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	68	41	.	PTI_1995
Cu	Oklahoma	GRID4	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	77.4	42	.	PTI_1995
Cu	Oklahoma	TERA	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	11.4	56	.	PTI_1995
Cu	Oklahoma	TERB	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	21.9	111	.	PTI_1995
Cu	Oklahoma	TERC	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	20.3	50	.	PTI_1995
Cu	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	186	37	.	PTI_1995
Cu	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	186	54	.	PTI_1995
Cu	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	63.7	31	.	PTI_1995
Fe	Oklahoma	GRID1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	26100	203	.	PTI_1995
Fe	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	19800	84	.	PTI_1995
Fe	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	19800	88	.	PTI_1995
Fe	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	15500	74.5	.	PTI_1995
Fe	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	15500	91	.	PTI_1995
Fe	Oklahoma	GRID4	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	20450	59	.	PTI_1995
Fe	Oklahoma	TERA	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	16800	454	.	PTI_1995
Fe	Oklahoma	TERB	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	32800	54	.	PTI_1995
Fe	Oklahoma	TERC	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	28200	135	.	PTI_1995
Fe	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	27000	52	.	PTI_1995
Fe	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	27000	80	.	PTI_1995

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	*Species*	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Fe	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	19300	56	.	PTI_1995
Pb	Oklahoma	GRID1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	83.9	4.1	.	PTI_1995
Pb	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	435	0.38	.	PTI_1995
Pb	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	435	0.68	.	PTI_1995
Pb	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	261	0.46	.	PTI_1995
Pb	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	261	0.62	.	PTI_1995
Pb	Oklahoma	GRID4	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	281.5	0.19	.	PTI_1995
Pb	Oklahoma	TERA	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	26.7	0.16	.	PTI_1995
Pb	Oklahoma	TERB	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	55.6	0.08	.	PTI_1995
Pb	Oklahoma	TERC	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	26.5	0.11	.	PTI_1995
Pb	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	485	0.45	.	PTI_1995
Pb	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	485	0.82	.	PTI_1995
Pb	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	179	0.22	.	PTI_1995
Mg	Oklahoma	GRID1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	2850	1270	.	PTI_1995
Mg	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	1750	1090	.	PTI_1995
Mg	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	1750	1230	.	PTI_1995
Mg	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	1340	1070	.	PTI_1995
Mg	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	1340	1120	.	PTI_1995
Mg	Oklahoma	GRID4	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	2120	1220	.	PTI_1995
Mg	Oklahoma	TERA	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	1450	1040	.	PTI_1995
Mg	Oklahoma	TERB	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	2170	1040	.	PTI_1995
Mg	Oklahoma	TERC	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	3400	1100	.	PTI_1995
Mg	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	2530	1100	.	PTI_1995
Mg	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	2530	1180	.	PTI_1995
Mg	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	2140	1160	.	PTI_1995
Mn	Oklahoma	GRID1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	486	10.8	.	PTI_1995
Mn	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	578	10.9	.	PTI_1995
Mn	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	578	36.4	.	PTI_1995
Mn	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	455	40.4	.	PTI_1995
Mn	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	455	45	.	PTI_1995
Mn	Oklahoma	GRID4	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	583	21.9	.	PTI_1995
Mn	Oklahoma	TERA	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	150	95.7	.	PTI_1995
Mn	Oklahoma	TERB	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	285	24.7	.	PTI_1995
Mn	Oklahoma	TERC	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	1260	28.6	.	PTI_1995
Mn	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	615	5.7	.	PTI_1995
Mn	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	615	32.4	.	PTI_1995
Mn	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	524	23.5	.	PTI_1995
Hg	Oklahoma	GRID1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.09	0.05	.	PTI_1995
Hg	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.19	0.05	.	PTI_1995
Hg	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.19	0.05	.	PTI_1995
Hg	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.05	0.05	.	PTI_1995
Hg	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.05	0.05	.	PTI_1995
Hg	Oklahoma	GRID4	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.09	0.05	.	PTI_1995
Hg	Oklahoma	TERA	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.03	0.06	.	PTI_1995
Hg	Oklahoma	TERB	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.05	0.08	.	PTI_1995
Hg	Oklahoma	TERC	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.06	0.05	.	PTI_1995
Hg	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.86	0.05	.	PTI_1995
Hg	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.86	0.05	.	PTI_1995
Hg	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.08	0.05	.	PTI_1995
Ni	Oklahoma	GRID1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	26	2	.	PTI_1995
Ni	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	17.5	2	.	PTI_1995
Ni	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	17.5	2	.	PTI_1995
Ni	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	10.2	2	.	PTI_1995
Ni	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	10.2	2	.	PTI_1995

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	Species	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Ni	Oklahoma	GRID4	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	19.15	2	.	PTI_1995
Ni	Oklahoma	TERA	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	9.9	2	.	PTI_1995
Ni	Oklahoma	TERB	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	15.1	2	.	PTI_1995
Ni	Oklahoma	TERC	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	36.4	2	.	PTI_1995
Ni	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	27.9	2	.	PTI_1995
Ni	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	27.9	2	.	PTI_1995
Ni	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	20.2	2	.	PTI_1995
K	Oklahoma	GRID1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	1400	9180	.	PTI_1995
K	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	1850	10900	.	PTI_1995
K	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	1850	12100	.	PTI_1995
K	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	1410	9770	.	PTI_1995
K	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	1410	10800	.	PTI_1995
K	Oklahoma	GRID4	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	2325	9680	.	PTI_1995
K	Oklahoma	TERA	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	1440	9680	.	PTI_1995
K	Oklahoma	TERB	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	2000	8140	.	PTI_1995
K	Oklahoma	TERC	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	3040	10500	.	PTI_1995
K	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	1980	9220	.	PTI_1995
K	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	1980	9900	.	PTI_1995
K	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	2320	9930	.	PTI_1995
Se	Oklahoma	GRID1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.2	1	U	PTI_1995
Se	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.94	1	.	PTI_1995
Se	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.94	1	.	PTI_1995
Se	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.53	1	.	PTI_1995
Se	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.53	2	.	PTI_1995
Se	Oklahoma	GRID4	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.62	1	.	PTI_1995
Se	Oklahoma	TERA	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.3	1	U	PTI_1995
Se	Oklahoma	TERB	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.3	1	U	PTI_1995
Se	Oklahoma	TERC	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.33	1	J	PTI_1995
Se	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	19.2	2	.	PTI_1995
Se	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	19.2	3	.	PTI_1995
Se	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.57	1	.	PTI_1995
Ag	Oklahoma	GRID1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	1	0.12	J	PTI_1995
Ag	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	6.9	0.27	J	PTI_1995
Ag	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	6.9	0.3	J	PTI_1995
Ag	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	3	0.15	J	PTI_1995
Ag	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	3	0.15	J	PTI_1995
Ag	Oklahoma	GRID4	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	2.9	0.05	J	PTI_1995
Ag	Oklahoma	TERA	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.59	0.02	J	PTI_1995
Ag	Oklahoma	TERB	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	1.2	0.02	J	PTI_1995
Ag	Oklahoma	TERC	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	0.5	0.02	UJ	PTI_1995
Ag	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	5.4	0.12	J	PTI_1995
Ag	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	5.4	0.16	J	PTI_1995
Ag	Oklahoma	TRAP2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	2.1	0.03	J	PTI_1995
Na	Oklahoma	GRID1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	148	770	.	PTI_1995
Na	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	49.3	1070	.	PTI_1995
Na	Oklahoma	GRID2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	49.3	1150	.	PTI_1995
Na	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	86.2	1080	.	PTI_1995
Na	Oklahoma	GRID3	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	86.2	1080	.	PTI_1995
Na	Oklahoma	GRID4	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	61.4	872	.	PTI_1995
Na	Oklahoma	TERA	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	40.6	734	.	PTI_1995
Na	Oklahoma	TERB	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	67.6	644	.	PTI_1995
Na	Oklahoma	TERC	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	78.1	485	.	PTI_1995
Na	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	395	1040	.	PTI_1995
Na	Oklahoma	TRAP1	field	resident	herbivore	Insecta	Orthoptera	Acrididae	grasshopper	.	395	1110	.	PTI_1995

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	*Species*	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
As	Oklahoma	TERC	field	resident	predator	Arachinida	Araneae	.	spider	.	6.3	0.5	.	PTI_1995
Ba	Oklahoma	GRID1	field	resident	predator	Arachinida	Araneae	.	spider	.	151	2.8	.	PTI_1995
Ba	Oklahoma	GRID2	field	resident	predator	Arachinida	Araneae	.	spider	.	160	2.5	.	PTI_1995
Ba	Oklahoma	GRID4	field	resident	predator	Arachinida	Araneae	.	spider	.	164	4.5	.	PTI_1995
Ba	Oklahoma	TERA	field	resident	predator	Arachinida	Araneae	.	spider	.	98.2	6.6	.	PTI_1995
Ba	Oklahoma	TERB	field	resident	predator	Arachinida	Araneae	.	spider	.	131	5	.	PTI_1995
Ba	Oklahoma	TERC	field	resident	predator	Arachinida	Araneae	.	spider	.	222	5.8	.	PTI_1995
Be	Oklahoma	GRID1	field	resident	predator	Arachinida	Araneae	.	spider	.	1.2	0.04	.	PTI_1995
Be	Oklahoma	GRID2	field	resident	predator	Arachinida	Araneae	.	spider	.	0.95	0.02	.	PTI_1995
Be	Oklahoma	GRID4	field	resident	predator	Arachinida	Araneae	.	spider	.	0.95	0.02	.	PTI_1995
Be	Oklahoma	TERA	field	resident	predator	Arachinida	Araneae	.	spider	.	0.7	0.02	.	PTI_1995
Be	Oklahoma	TERB	field	resident	predator	Arachinida	Araneae	.	spider	.	1.4	0.02	.	PTI_1995
Be	Oklahoma	TERC	field	resident	predator	Arachinida	Araneae	.	spider	.	1.2	0.02	.	PTI_1995
Cd	Oklahoma	GRID1	field	resident	predator	Arachinida	Araneae	.	spider	.	26.6	29.7	J	PTI_1995
Cd	Oklahoma	GRID2	field	resident	predator	Arachinida	Araneae	.	spider	.	69.8	8.6	J	PTI_1995
Cd	Oklahoma	GRID4	field	resident	predator	Arachinida	Araneae	.	spider	.	33.1	17.6	J	PTI_1995
Cd	Oklahoma	TERA	field	resident	predator	Arachinida	Araneae	.	spider	.	0.89	10	J	PTI_1995
Cd	Oklahoma	TERB	field	resident	predator	Arachinida	Araneae	.	spider	.	3.4	9.7	J	PTI_1995
Cd	Oklahoma	TERC	field	resident	predator	Arachinida	Araneae	.	spider	.	0.6	5.1	U	PTI_1995
Ca	Oklahoma	GRID1	field	resident	predator	Arachinida	Araneae	.	spider	.	13000	1960	.	PTI_1995
Ca	Oklahoma	GRID2	field	resident	predator	Arachinida	Araneae	.	spider	.	2500	1250	.	PTI_1995
Ca	Oklahoma	GRID4	field	resident	predator	Arachinida	Araneae	.	spider	.	3715	2100	.	PTI_1995
Ca	Oklahoma	TERA	field	resident	predator	Arachinida	Araneae	.	spider	.	1670	2500	.	PTI_1995
Ca	Oklahoma	TERB	field	resident	predator	Arachinida	Araneae	.	spider	.	2330	2000	.	PTI_1995
Ca	Oklahoma	TERC	field	resident	predator	Arachinida	Araneae	.	spider	.	66200	3120	.	PTI_1995
Cr	Oklahoma	GRID1	field	resident	predator	Arachinida	Araneae	.	spider	.	27.3	10.9	.	PTI_1995
Cr	Oklahoma	GRID2	field	resident	predator	Arachinida	Araneae	.	spider	.	24.7	4.6	.	PTI_1995
Cr	Oklahoma	GRID4	field	resident	predator	Arachinida	Araneae	.	spider	.	26.45	1.3	.	PTI_1995
Cr	Oklahoma	TERA	field	resident	predator	Arachinida	Araneae	.	spider	.	24.3	10.7	.	PTI_1995
Cr	Oklahoma	TERB	field	resident	predator	Arachinida	Araneae	.	spider	.	39.7	1.8	.	PTI_1995
Cr	Oklahoma	TERC	field	resident	predator	Arachinida	Araneae	.	spider	.	33.4	1.6	.	PTI_1995
Co	Oklahoma	GRID1	field	resident	predator	Arachinida	Araneae	.	spider	.	15.6	0.11	.	PTI_1995
Co	Oklahoma	GRID2	field	resident	predator	Arachinida	Araneae	.	spider	.	9.2	0.04	.	PTI_1995
Co	Oklahoma	GRID4	field	resident	predator	Arachinida	Araneae	.	spider	.	10.15	0.07	.	PTI_1995
Co	Oklahoma	TERA	field	resident	predator	Arachinida	Araneae	.	spider	.	6.4	0.24	.	PTI_1995
Co	Oklahoma	TERB	field	resident	predator	Arachinida	Araneae	.	spider	.	8.8	0.09	.	PTI_1995
Co	Oklahoma	TERC	field	resident	predator	Arachinida	Araneae	.	spider	.	13	0.09	.	PTI_1995
Cu	Oklahoma	GRID1	field	resident	predator	Arachinida	Araneae	.	spider	.	47.6	95	.	PTI_1995
Cu	Oklahoma	GRID2	field	resident	predator	Arachinida	Araneae	.	spider	.	180	56	.	PTI_1995
Cu	Oklahoma	GRID4	field	resident	predator	Arachinida	Araneae	.	spider	.	77.4	56	.	PTI_1995
Cu	Oklahoma	TERA	field	resident	predator	Arachinida	Araneae	.	spider	.	11.4	105	.	PTI_1995
Cu	Oklahoma	TERB	field	resident	predator	Arachinida	Araneae	.	spider	.	21.9	79	.	PTI_1995
Cu	Oklahoma	TERC	field	resident	predator	Arachinida	Araneae	.	spider	.	20.3	72	.	PTI_1995
Fe	Oklahoma	GRID1	field	resident	predator	Arachinida	Araneae	.	spider	.	26100	533	.	PTI_1995
Fe	Oklahoma	GRID2	field	resident	predator	Arachinida	Araneae	.	spider	.	19800	267	.	PTI_1995
Fe	Oklahoma	GRID4	field	resident	predator	Arachinida	Araneae	.	spider	.	20450	230	.	PTI_1995
Fe	Oklahoma	TERA	field	resident	predator	Arachinida	Araneae	.	spider	.	16800	1720	.	PTI_1995
Fe	Oklahoma	TERB	field	resident	predator	Arachinida	Araneae	.	spider	.	32800	210	.	PTI_1995
Fe	Oklahoma	TERC	field	resident	predator	Arachinida	Araneae	.	spider	.	28200	473	.	PTI_1995
Pb	Oklahoma	GRID1	field	resident	predator	Arachinida	Araneae	.	spider	.	83.9	3.1	.	PTI_1995
Pb	Oklahoma	GRID2	field	resident	predator	Arachinida	Araneae	.	spider	.	435	1	.	PTI_1995
Pb	Oklahoma	GRID4	field	resident	predator	Arachinida	Araneae	.	spider	.	281.5	0.52	.	PTI_1995
Pb	Oklahoma	TERA	field	resident	predator	Arachinida	Araneae	.	spider	.	26.7	0.47	.	PTI_1995
Pb	Oklahoma	TERB	field	resident	predator	Arachinida	Araneae	.	spider	.	55.6	0.32	.	PTI_1995

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	*Species*	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Pb	Oklahoma	TERC	field	resident	predator	Arachinida	Araneae	.	spider	.	26.5	0.28	.	PTI_1995
Mg	Oklahoma	GRID1	field	resident	predator	Arachinida	Araneae	.	spider	.	2850	1770	.	PTI_1995
Mg	Oklahoma	GRID2	field	resident	predator	Arachinida	Araneae	.	spider	.	1750	1780	.	PTI_1995
Mg	Oklahoma	GRID4	field	resident	predator	Arachinida	Araneae	.	spider	.	2120	1920	.	PTI_1995
Mg	Oklahoma	TERA	field	resident	predator	Arachinida	Araneae	.	spider	.	1450	2120	.	PTI_1995
Mg	Oklahoma	TERB	field	resident	predator	Arachinida	Araneae	.	spider	.	2170	2020	.	PTI_1995
Mg	Oklahoma	TERC	field	resident	predator	Arachinida	Araneae	.	spider	.	3400	2120	.	PTI_1995
Mn	Oklahoma	GRID1	field	resident	predator	Arachinida	Araneae	.	spider	.	486	24	.	PTI_1995
Mn	Oklahoma	GRID2	field	resident	predator	Arachinida	Araneae	.	spider	.	578	21.9	.	PTI_1995
Mn	Oklahoma	GRID4	field	resident	predator	Arachinida	Araneae	.	spider	.	583	21.3	.	PTI_1995
Mn	Oklahoma	TERA	field	resident	predator	Arachinida	Araneae	.	spider	.	150	41.6	.	PTI_1995
Mn	Oklahoma	TERB	field	resident	predator	Arachinida	Araneae	.	spider	.	285	36.6	.	PTI_1995
Mn	Oklahoma	TERC	field	resident	predator	Arachinida	Araneae	.	spider	.	1260	35.2	.	PTI_1995
Hg	Oklahoma	GRID1	field	resident	predator	Arachinida	Araneae	.	spider	.	0.09	0.08	.	PTI_1995
Hg	Oklahoma	GRID2	field	resident	predator	Arachinida	Araneae	.	spider	.	0.19	0.06	.	PTI_1995
Hg	Oklahoma	GRID4	field	resident	predator	Arachinida	Araneae	.	spider	.	0.09	0.05	.	PTI_1995
Hg	Oklahoma	TERA	field	resident	predator	Arachinida	Araneae	.	spider	.	0.03	0.2	.	PTI_1995
Hg	Oklahoma	TERB	field	resident	predator	Arachinida	Araneae	.	spider	.	0.05	0.06	.	PTI_1995
Hg	Oklahoma	TERC	field	resident	predator	Arachinida	Araneae	.	spider	.	0.06	0.13	.	PTI_1995
Ni	Oklahoma	GRID1	field	resident	predator	Arachinida	Araneae	.	spider	.	26	4	.	PTI_1995
Ni	Oklahoma	GRID2	field	resident	predator	Arachinida	Araneae	.	spider	.	17.5	2	.	PTI_1995
Ni	Oklahoma	GRID4	field	resident	predator	Arachinida	Araneae	.	spider	.	19.15	2	.	PTI_1995
Ni	Oklahoma	TERA	field	resident	predator	Arachinida	Araneae	.	spider	.	9.9	4	.	PTI_1995
Ni	Oklahoma	TERB	field	resident	predator	Arachinida	Araneae	.	spider	.	15.1	2	.	PTI_1995
Ni	Oklahoma	TERC	field	resident	predator	Arachinida	Araneae	.	spider	.	36.4	2	.	PTI_1995
K	Oklahoma	GRID1	field	resident	predator	Arachinida	Araneae	.	spider	.	1400	10300	.	PTI_1995
K	Oklahoma	GRID2	field	resident	predator	Arachinida	Araneae	.	spider	.	1850	9050	.	PTI_1995
K	Oklahoma	GRID4	field	resident	predator	Arachinida	Araneae	.	spider	.	2325	9880	.	PTI_1995
K	Oklahoma	TERA	field	resident	predator	Arachinida	Araneae	.	spider	.	1440	11100	.	PTI_1995
K	Oklahoma	TERB	field	resident	predator	Arachinida	Araneae	.	spider	.	2000	9670	.	PTI_1995
K	Oklahoma	TERC	field	resident	predator	Arachinida	Araneae	.	spider	.	3040	11000	.	PTI_1995
Se	Oklahoma	GRID1	field	resident	predator	Arachinida	Araneae	.	spider	.	0.2	2	U	PTI_1995
Se	Oklahoma	GRID2	field	resident	predator	Arachinida	Araneae	.	spider	.	0.94	1	.	PTI_1995
Se	Oklahoma	GRID4	field	resident	predator	Arachinida	Araneae	.	spider	.	0.62	2	.	PTI_1995
Se	Oklahoma	TERA	field	resident	predator	Arachinida	Araneae	.	spider	.	0.3	2	U	PTI_1995
Se	Oklahoma	TERB	field	resident	predator	Arachinida	Araneae	.	spider	.	0.3	1	U	PTI_1995
Se	Oklahoma	TERC	field	resident	predator	Arachinida	Araneae	.	spider	.	0.33	2	J	PTI_1995
Ag	Oklahoma	GRID1	field	resident	predator	Arachinida	Araneae	.	spider	.	1	0.59	J	PTI_1995
Ag	Oklahoma	GRID2	field	resident	predator	Arachinida	Araneae	.	spider	.	6.9	0.37	J	PTI_1995
Ag	Oklahoma	GRID4	field	resident	predator	Arachinida	Araneae	.	spider	.	2.9	0.32	J	PTI_1995
Ag	Oklahoma	TERA	field	resident	predator	Arachinida	Araneae	.	spider	.	0.59	0.59	J	PTI_1995
Ag	Oklahoma	TERB	field	resident	predator	Arachinida	Araneae	.	spider	.	1.2	0.43	J	PTI_1995
Ag	Oklahoma	TERC	field	resident	predator	Arachinida	Araneae	.	spider	.	0.5	0.17	UJ	PTI_1995
Na	Oklahoma	GRID1	field	resident	predator	Arachinida	Araneae	.	spider	.	148	3810	.	PTI_1995
Na	Oklahoma	GRID2	field	resident	predator	Arachinida	Araneae	.	spider	.	49.3	2680	.	PTI_1995
Na	Oklahoma	GRID4	field	resident	predator	Arachinida	Araneae	.	spider	.	61.4	2000	.	PTI_1995
Na	Oklahoma	TERA	field	resident	predator	Arachinida	Araneae	.	spider	.	40.6	3240	.	PTI_1995
Na	Oklahoma	TERB	field	resident	predator	Arachinida	Araneae	.	spider	.	67.6	2400	.	PTI_1995
Na	Oklahoma	TERC	field	resident	predator	Arachinida	Araneae	.	spider	.	78.1	2330	.	PTI_1995
Tl	Oklahoma	GRID1	field	resident	predator	Arachinida	Araneae	.	spider	.	0.36	0.04	J	PTI_1995
Tl	Oklahoma	GRID2	field	resident	predator	Arachinida	Araneae	.	spider	.	0.38	0.02	J	PTI_1995
Tl	Oklahoma	GRID4	field	resident	predator	Arachinida	Araneae	.	spider	.	0.33	0.02	J	PTI_1995
Tl	Oklahoma	TERA	field	resident	predator	Arachinida	Araneae	.	spider	.	0.39	0.02	J	PTI_1995
Tl	Oklahoma	TERB	field	resident	predator	Arachinida	Araneae	.	spider	.	0.38	0.02	J	PTI_1995

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	Species	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Tl	Oklahoma	TERC	field	resident	predator	Arachinida	Araneae	.	spider	.	1.4	0.02	UJ	PTI_1995
V	Oklahoma	GRID1	field	resident	predator	Arachinida	Araneae	.	spider	.	30.7	0.3	.	PTI_1995
V	Oklahoma	GRID2	field	resident	predator	Arachinida	Araneae	.	spider	.	30.4	0.3	.	PTI_1995
V	Oklahoma	GRID4	field	resident	predator	Arachinida	Araneae	.	spider	.	30.85	0.2	.	PTI_1995
V	Oklahoma	TERA	field	resident	predator	Arachinida	Araneae	.	spider	.	24.8	0.1	.	PTI_1995
V	Oklahoma	TERB	field	resident	predator	Arachinida	Araneae	.	spider	.	44.5	0.2	.	PTI_1995
V	Oklahoma	TERC	field	resident	predator	Arachinida	Araneae	.	spider	.	33.7	0.5	.	PTI_1995
Zn	Oklahoma	GRID1	field	resident	predator	Arachinida	Araneae	.	spider	.	3210	631	.	PTI_1995
Zn	Oklahoma	GRID2	field	resident	predator	Arachinida	Araneae	.	spider	.	3750	365	.	PTI_1995
Zn	Oklahoma	GRID4	field	resident	predator	Arachinida	Araneae	.	spider	.	2135	336	.	PTI_1995
Zn	Oklahoma	TERA	field	resident	predator	Arachinida	Araneae	.	spider	.	154	415	.	PTI_1995
Zn	Oklahoma	TERB	field	resident	predator	Arachinida	Araneae	.	spider	.	413	319	.	PTI_1995
Zn	Oklahoma	TERC	field	resident	predator	Arachinida	Araneae	.	spider	.	169	328	.	PTI_1995
Cd	Austria	1	field	resident	detritivore	Diplopoda	.	.	*diplopoda-M._mutabilis*	.	23.30	23.4	.	Rabitsch_1995a
Cd	Austria	1	field	resident	detritivore	Diplopoda	.	.	*diplopoda-O._pusilla*	.	23.30	34.5	.	Rabitsch_1995a
Cd	Austria	3	field	resident	detritivore	Diplopoda	.	.	*diplopoda-O._pusilla*	.	42.70	49.7	.	Rabitsch_1995a
Cd	Austria	4	field	resident	detritivore	Diplopoda	.	.	*diplopoda-M._mutabilis*	.	35.00	16.6	.	Rabitsch_1995a
Cd	Austria	4	field	resident	detritivore	Diplopoda	.	.	*diplopoda-O._pusilla*	.	35.00	20.5	.	Rabitsch_1995a
Cd	Austria	5	field	resident	detritivore	Diplopoda	.	.	*diplopoda-P._complanatus*	.	2.50	2.9	.	Rabitsch_1995a
Cu	Austria	1	field	resident	detritivore	Diplopoda	.	.	*diplopoda-M._mutabilis*	.	113.50	183.7	.	Rabitsch_1995a
Cu	Austria	1	field	resident	detritivore	Diplopoda	.	.	*diplopoda-O._pusilla*	.	113.50	338.5	.	Rabitsch_1995a
Cu	Austria	3	field	resident	detritivore	Diplopoda	.	.	*diplopoda-O._pusilla*	.	294.90	371.7	.	Rabitsch_1995a
Cu	Austria	4	field	resident	detritivore	Diplopoda	.	.	*diplopoda-M._mutabilis*	.	129.70	200.4	.	Rabitsch_1995a
Cu	Austria	4	field	resident	detritivore	Diplopoda	.	.	*diplopoda-O._pusilla*	.	129.70	413.2	.	Rabitsch_1995a
Cu	Austria	5	field	resident	detritivore	Diplopoda	.	.	*diplopoda-P._complanatus*	.	36.50	192.6	.	Rabitsch_1995a
Pb	Austria	1	field	resident	detritivore	Diplopoda	.	.	*diplopoda-O._pusilla*	.	1695.00	124.2	.	Rabitsch_1995a
Pb	Austria	1	field	resident	detritivore	Diplopoda	.	.	*diplopoda-M._mutabilis*	.	1695.00	124.7	.	Rabitsch_1995a
Pb	Austria	3	field	resident	detritivore	Diplopoda	.	.	*diplopoda-O._pusilla*	.	8928.00	390.8	.	Rabitsch_1995a
Pb	Austria	4	field	resident	detritivore	Diplopoda	.	.	*diplopoda-O._pusilla*	.	4665.00	139.5	.	Rabitsch_1995a
Pb	Austria	4	field	resident	detritivore	Diplopoda	.	.	*diplopoda-M._mutabilis*	.	4665.00	271.3	.	Rabitsch_1995a
Pb	Austria	5	field	resident	detritivore	Diplopoda	.	.	*diplopoda-P._complanatus*	.	574.00	22.9	.	Rabitsch_1995a
Zn	Austria	1	field	resident	detritivore	Diplopoda	.	.	*diplopoda-O._pusilla*	.	1697.00	1687	.	Rabitsch_1995a
Zn	Austria	1	field	resident	detritivore	Diplopoda	.	.	*diplopoda-M._mutabilis*	.	1697.00	2044	.	Rabitsch_1995a
Zn	Austria	3	field	resident	detritivore	Diplopoda	.	.	*diplopoda-O._pusilla*	.	7795.00	1599	.	Rabitsch_1995a
Zn	Austria	4	field	resident	detritivore	Diplopoda	.	.	*diplopoda-O._pusilla*	.	5813.00	984	.	Rabitsch_1995a
Zn	Austria	4	field	resident	detritivore	Diplopoda	.	.	*diplopoda-M._mutabilis*	.	5813.00	1759	.	Rabitsch_1995a
Zn	Austria	5	field	resident	detritivore	Diplopoda	.	.	*diplopoda-P._complanatus*	.	329.00	599	.	Rabitsch_1995a
Cd	Austria	1	field	resident	detritivore	Isopoda	.	.	*isopoda-T._ratzeburgi*	.	23.30	47.7	.	Rabitsch_1995a
Cd	Austria	2	field	resident	detritivore	Isopoda	.	.	*isopoda-P._scaber*	.	82.10	16.3	.	Rabitsch_1995a
Cd	Austria	2	field	resident	detritivore	Isopoda	.	.	*isopoda-T._rathkei*	.	82.10	30.2	.	Rabitsch_1995a
Cd	Austria	4	field	resident	detritivore	Isopoda	.	.	*isopoda-T._ratzeburgi*	.	35.00	64.9	.	Rabitsch_1995a
Cd	Austria	5	field	resident	detritivore	Isopoda	.	.	*isopoda-T._ratzeburgi*	.	2.50	17.7	.	Rabitsch_1995a
Cu	Austria	1	field	resident	detritivore	Isopoda	.	.	*isopoda-T._ratzeburgi*	.	113.50	354.6	.	Rabitsch_1995a
Cu	Austria	2	field	resident	detritivore	Isopoda	.	.	*isopoda-T._rathkei*	.	1900.30	81.7	.	Rabitsch_1995a
Cu	Austria	2	field	resident	detritivore	Isopoda	.	.	*isopoda-P._scaber*	.	1900.30	185.8	.	Rabitsch_1995a
Cu	Austria	4	field	resident	detritivore	Isopoda	.	.	*isopoda-T._ratzeburgi*	.	129.70	455.4	.	Rabitsch_1995a
Cu	Austria	5	field	resident	detritivore	Isopoda	.	.	*isopoda-T._ratzeburgi*	.	36.50	425.2	.	Rabitsch_1995a
Pb	Austria	1	field	resident	detritivore	Isopoda	.	.	*isopoda-T._ratzeburgi*	.	1695.00	773.2	.	Rabitsch_1995a
Pb	Austria	2	field	resident	detritivore	Isopoda	.	.	*isopoda-P._scaber*	.	93768.00	123.8	.	Rabitsch_1995a
Pb	Austria	2	field	resident	detritivore	Isopoda	.	.	*isopoda-T._rathkei*	.	93768.00	386.1	.	Rabitsch_1995a
Pb	Austria	4	field	resident	detritivore	Isopoda	.	.	*isopoda-T._ratzeburgi*	.	4465.00	1145.7	.	Rabitsch_1995a
Pb	Austria	5	field	resident	detritivore	Isopoda	.	.	*isopoda-T._ratzeburgi*	.	574.00	166.2	.	Rabitsch_1995a
Zn	Austria	1	field	resident	detritivore	Isopoda	.	.	*isopoda-T._ratzeburgi*	.	1697.00	1168	.	Rabitsch_1995a
Zn	Austria	2	field	resident	detritivore	Isopoda	.	.	*isopoda-P._scaber*	.	8050.00	970	.	Rabitsch_1995a

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	*Species*	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Zn	Austria	2	field	resident	detritivore	Isopoda	.	.	*isopoda-T._rathkei*	.	8050.00	1150	.	Rabitsch_1995a
Zn	Austria	4	field	resident	detritivore	Isopoda	.	.	*isopoda-T._ratzeburgi*	.	5813.00	2430	.	Rabitsch_1995a
Zn	Austria	5	field	resident	detritivore	Isopoda	.	.	*isopoda-T._ratzeburgi*	.	329.00	857.5	.	Rabitsch_1995a
Cd	Austria	2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	*Orthoptera-C._montanus*	.	82.10	12.1	.	Rabitsch_1995a
Cu	Austria	2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	*Orthoptera-C._montanus*	.	1900.30	136.5	.	Rabitsch_1995a
Pb	Austria	2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	*Orthoptera-C._montanus*	.	93768.00	306.2	.	Rabitsch_1995a
Zn	Austria	2	field	resident	herbivore	Insecta	Orthoptera	Acrididae	*Orthoptera-C._montanus*	.	8050.00	701	.	Rabitsch_1995a
Cd	Austria	2	field	resident	herbivore	Insecta	Coleoptera	Curculionidae	*curculionidae-O._crategi*	.	82.10	5.5	.	Rabitsch_1995a
Cd	Austria	2	field	resident	herbivore	Insecta	Coleoptera	Curculionidae	*curculionidae-O._ovatus*	.	82.10	9.9	.	Rabitsch_1995a
Cd	Austria	3	field	resident	herbivore	Insecta	Coleoptera	Curculionidae	*curculionidae-O._raucus*	.	42.70	2.7	.	Rabitsch_1995a
Cd	Austria	3	field	resident	herbivore	Insecta	Coleoptera	Curculionidae	*curculionidae-O._ovatus*	.	42.70	8.4	.	Rabitsch_1995a
Cd	Austria	4	field	resident	herbivore	Insecta	Coleoptera	Curculionidae	*curculionidae-H._abietus*	.	35.00	1.4	.	Rabitsch_1995a
Cu	Austria	2	field	resident	herbivore	Insecta	Coleoptera	Curculionidae	*curculionidae-O._crategi*	.	1900.30	9.4	.	Rabitsch_1995a
Cu	Austria	2	field	resident	herbivore	Insecta	Coleoptera	Curculionidae	*curculionidae-O._ovatus*	.	1900.30	20.5	.	Rabitsch_1995a
Cu	Austria	3	field	resident	herbivore	Insecta	Coleoptera	Curculionidae	*curculionidae-O._ovatus*	.	294.90	18.4	.	Rabitsch_1995a
Cu	Austria	3	field	resident	herbivore	Insecta	Coleoptera	Curculionidae	*curculionidae-O._raucus*	.	294.90	33.4	.	Rabitsch_1995a
Cu	Austria	4	field	resident	herbivore	Insecta	Coleoptera	Curculionidae	*curculionidae-H._abietus*	.	129.70	40.2	.	Rabitsch_1995a
Pb	Austria	2	field	resident	herbivore	Insecta	Coleoptera	Curculionidae	*curculionidae-O._crategi*	.	93768.00	292	.	Rabitsch_1995a
Pb	Austria	2	field	resident	herbivore	Insecta	Coleoptera	Curculionidae	*curculionidae-O._ovatus*	.	93768.00	726	.	Rabitsch_1995a
Pb	Austria	3	field	resident	herbivore	Insecta	Coleoptera	Curculionidae	*curculionidae-O._raucus*	.	8928.00	94.5	.	Rabitsch_1995a
Pb	Austria	3	field	resident	herbivore	Insecta	Coleoptera	Curculionidae	*curculionidae-O._ovatus*	.	8928.00	353	.	Rabitsch_1995a
Pb	Austria	4	field	resident	herbivore	Insecta	Coleoptera	Curculionidae	*curculionidae-H._abietus*	.	4665.00	28.2	.	Rabitsch_1995a
Zn	Austria	2	field	resident	herbivore	Insecta	Coleoptera	Curculionidae	*curculionidae-O._ovatus*	.	8050.00	137.9	.	Rabitsch_1995a
Zn	Austria	2	field	resident	herbivore	Insecta	Coleoptera	Curculionidae	*curculionidae-O._crategi*	.	8050.00	205.6	.	Rabitsch_1995a
Zn	Austria	3	field	resident	herbivore	Insecta	Coleoptera	Curculionidae	*curculionidae-O._raucus*	.	7795.00	80.3	.	Rabitsch_1995a
Zn	Austria	3	field	resident	herbivore	Insecta	Coleoptera	Curculionidae	*curculionidae-O._ovatus*	.	7795.00	98.7	.	Rabitsch_1995a
Zn	Austria	4	field	resident	herbivore	Insecta	Coleoptera	Curculionidae	*curculionidae-H._abietus*	.	5813.00	78.8	.	Rabitsch_1995a
Cd	Austria	5	field	resident	omnivore	Insecta	Orthoptera	Blattodidae	*Blattodea-E._sylvestris*	.	2.50	3.5	.	Rabitsch_1995a
Cu	Austria	5	field	resident	omnivore	Insecta	Orthoptera	Blattodidae	*Blattodea-E._sylvestris*	.	36.50	16.4	.	Rabitsch_1995a
Pb	Austria	5	field	resident	omnivore	Insecta	Orthoptera	Blattodidae	*Blattodea-E._sylvestris*	.	574.00	34	.	Rabitsch_1995a
Zn	Austria	5	field	resident	omnivore	Insecta	Orthoptera	Blattodidae	*Blattodea-E._sylvestris*	.	329.00	267	.	Rabitsch_1995a
Cd	Austria	1	field	resident	predator	Chilopoda	.	.	*chilopoda_-_L._tricuspis*	.	23.30	7.9	.	Rabitsch_1995a
Cd	Austria	2	field	resident	predator	Chilopoda	.	.	*chilopoda_-_L._forficatus*	.	82.10	4.8	.	Rabitsch_1995a
Cd	Austria	4	field	resident	predator	Chilopoda	.	.	*chilopoda_-_L._forficatus*	.	35.00	4.8	.	Rabitsch_1995a
Cd	Austria	5	field	resident	predator	Chilopoda	.	.	*chilopoda_-_E._grossipes*	.	2.50	8	.	Rabitsch_1995a
Cu	Austria	1	field	resident	predator	Chilopoda	.	.	*chilopoda_-_L._tricuspis*	.	113.50	31.5	.	Rabitsch_1995a
Cu	Austria	2	field	resident	predator	Chilopoda	.	.	*chilopoda_-_L._forficatus*	.	1900.30	41.6	.	Rabitsch_1995a
Cu	Austria	4	field	resident	predator	Chilopoda	.	.	*chilopoda_-_L._forficatus*	.	129.70	37.7	.	Rabitsch_1995a
Cu	Austria	5	field	resident	predator	Chilopoda	.	.	*chilopoda_-_E._grossipes*	.	36.50	58.2	.	Rabitsch_1995a
Pb	Austria	1	field	resident	predator	Chilopoda	.	.	*chilopoda_-_L._tricuspis*	.	1695.00	27.3	.	Rabitsch_1995a
Pb	Austria	2	field	resident	predator	Chilopoda	.	.	*chilopoda_-_L._forficatus*	.	93768.00	29.4	.	Rabitsch_1995a
Pb	Austria	4	field	resident	predator	Chilopoda	.	.	*chilopoda_-_L._forficatus*	.	4665.00	60	.	Rabitsch_1995a
Pb	Austria	5	field	resident	predator	Chilopoda	.	.	*chilopoda_-_E._grossipes*	.	574.00	12.7	.	Rabitsch_1995a
Zn	Austria	1	field	resident	predator	Chilopoda	.	.	*chilopoda_-_L._tricuspis*	.	1697.00	773	.	Rabitsch_1995a
Zn	Austria	2	field	resident	predator	Chilopoda	.	.	*chilopoda_-_L._forficatus*	.	8050.00	1064	.	Rabitsch_1995a
Zn	Austria	4	field	resident	predator	Chilopoda	.	.	*chilopoda_-_L._forficatus*	.	5813.00	606	.	Rabitsch_1995a
Zn	Austria	5	field	resident	predator	Chilopoda	.	.	*chilopoda_-_E._grossipes*	.	329.00	519	.	Rabitsch_1995a
Cd	Austria	1	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-P._versicolor*	.	23.30	4.1	.	Rabitsch_1995a
Cd	Austria	1	field	resident	predator	Insecta	Coleoptera	Carabidae	*arabidae-P._oblongopunctatu*	.	23.30	12.3	.	Rabitsch_1995a
Cd	Austria	2	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-H._rufipes*	.	82.10	4.4	.	Rabitsch_1995a
Cd	Austria	2	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-C._erratus*	.	82.10	7.6	.	Rabitsch_1995a
Cd	Austria	2	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-A._lunicollis*	.	82.10	14.9	.	Rabitsch_1995a
Cd	Austria	2	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-P._versicolor*	.	82.10	18.1	.	Rabitsch_1995a
Cd	Austria	4	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-C._hortensis*	.	35.00	7.6	.	Rabitsch_1995a

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	Species	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Cd	Austria	5	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-P._metallicus*	.	2.50	2.5	.	Rabitsch_1995a
Cd	Austria	5	field	resident	predator	Insecta	Coleoptera	Carabidae	*arabidae-P._oblongopunctatu*	.	2.50	2.8	.	Rabitsch_1995a
Cd	Austria	5	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-C._hortensis*	.	2.50	10.8	.	Rabitsch_1995a
Cu	Austria	1	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-P._versicolor*	.	113.50	14.9	.	Rabitsch_1995a
Cu	Austria	1	field	resident	predator	Insecta	Coleoptera	Carabidae	*arabidae-P._oblongopunctatu*	.	113.50	25.3	.	Rabitsch_1995a
Cu	Austria	2	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-H._rufipes*	.	1900.30	15.2	.	Rabitsch_1995a
Cu	Austria	2	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-P._versicolor*	.	1900.30	18.2	.	Rabitsch_1995a
Cu	Austria	2	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-C._erratus*	.	1900.30	28.1	.	Rabitsch_1995a
Cu	Austria	2	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-A._lunicollis*	.	1900.30	39.6	.	Rabitsch_1995a
Cu	Austria	4	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-C._hortensis*	.	129.70	12	.	Rabitsch_1995a
Cu	Austria	5	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-P._metallicus*	.	36.50	13.66	.	Rabitsch_1995a
Cu	Austria	5	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-C._hortensis*	.	36.50	14	.	Rabitsch_1995a
Cu	Austria	5	field	resident	predator	Insecta	Coleoptera	Carabidae	*arabidae-P._oblongopunctatu*	.	36.50	20.9	.	Rabitsch_1995a
Pb	Austria	1	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-P._versicolor*	.	1695.00	31.2	.	Rabitsch_1995a
Pb	Austria	1	field	resident	predator	Insecta	Coleoptera	Carabidae	*arabidae-P._oblongopunctatu*	.	1695.00	43.2	.	Rabitsch_1995a
Pb	Austria	2	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-H._rufipes*	.	93768.00	215	.	Rabitsch_1995a
Pb	Austria	2	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-P._versicolor*	.	93768.00	472	.	Rabitsch_1995a
Pb	Austria	2	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-C._erratus*	.	93768.00	617	.	Rabitsch_1995a
Pb	Austria	2	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-A._lunicollis*	.	93768.00	623	.	Rabitsch_1995a
Pb	Austria	4	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-C._hortensis*	.	4665.00	9.5	.	Rabitsch_1995a
Pb	Austria	5	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-C._hortensis*	.	574.00	3.8	.	Rabitsch_1995a
Pb	Austria	5	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-P._metallicus*	.	574.00	6.1	.	Rabitsch_1995a
Pb	Austria	5	field	resident	predator	Insecta	Coleoptera	Carabidae	*arabidae-P._oblongopunctatu*	.	574.00	12.1	.	Rabitsch_1995a
Zn	Austria	1	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-P._versicolor*	.	1697.00	247	.	Rabitsch_1995a
Zn	Austria	1	field	resident	predator	Insecta	Coleoptera	Carabidae	*arabidae-P._oblongopunctatu*	.	1697.00	298	.	Rabitsch_1995a
Zn	Austria	2	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-H._rufipes*	.	8050.00	287	.	Rabitsch_1995a
Zn	Austria	2	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-P._versicolor*	.	8050.00	394	.	Rabitsch_1995a
Zn	Austria	2	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-A._lunicollis*	.	8050.00	402	.	Rabitsch_1995a
Zn	Austria	2	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-C._erratus*	.	8050.00	475	.	Rabitsch_1995a
Zn	Austria	4	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-C._hortensis*	.	5813.00	113	.	Rabitsch_1995a
Zn	Austria	5	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-C._hortensis*	.	329.00	104	.	Rabitsch_1995a
Zn	Austria	5	field	resident	predator	Insecta	Coleoptera	Carabidae	*arabidae-P._oblongopunctatu*	.	329.00	125	.	Rabitsch_1995a
Zn	Austria	5	field	resident	predator	Insecta	Coleoptera	Carabidae	*carabidae-P._metallicus*	.	329.00	157	.	Rabitsch_1995a
Cd	Austria	1	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-P._fossor*	.	23.30	5.7	.	Rabitsch_1995a
Cd	Austria	1	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-Q._fuliginosus*	.	23.30	19.6	.	Rabitsch_1995a
Cd	Austria	3	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-Z._humeralis*	.	42.70	7.3	.	Rabitsch_1995a
Cd	Austria	3	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-X._linearis*	.	42.70	8.2	.	Rabitsch_1995a
Cd	Austria	3	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-P._fossor*	.	42.70	9.5	.	Rabitsch_1995a
Cd	Austria	3	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-G._circellaris*	.	42.70	16.7	.	Rabitsch_1995a
Cd	Austria	4	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-P._fossor*	.	35.00	16.5	.	Rabitsch_1995a
Cd	Austria	5	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-Q._fuliginosus*	.	2.50	6.6	.	Rabitsch_1995a
Cu	Austria	1	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-Q._fuliginosus*	.	113.50	14	.	Rabitsch_1995a
Cu	Austria	1	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-P._fossor*	.	113.50	37.3	.	Rabitsch_1995a
Cu	Austria	3	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-X._linearis*	.	294.90	14.5	.	Rabitsch_1995a
Cu	Austria	3	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-P._fossor*	.	294.90	27.6	.	Rabitsch_1995a
Cu	Austria	3	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-Z._humeralis*	.	294.90	41.9	.	Rabitsch_1995a
Cu	Austria	3	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-G._circellaris*	.	294.90	76.4	.	Rabitsch_1995a
Cu	Austria	4	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-P._fossor*	.	129.70	37.7	.	Rabitsch_1995a
Cu	Austria	5	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-Q._fuliginosus*	.	36.50	12.4	.	Rabitsch_1995a
Pb	Austria	1	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-P._fossor*	.	1695.00	20.9	.	Rabitsch_1995a
Pb	Austria	1	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-Q._fuliginosus*	.	1695.00	46	.	Rabitsch_1995a
Pb	Austria	3	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-P._fossor*	.	8928.00	51.8	.	Rabitsch_1995a
Pb	Austria	3	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-X._linearis*	.	8928.00	76.6	.	Rabitsch_1995a
Pb	Austria	3	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-Z._humeralis*	.	8928.00	107	.	Rabitsch_1995a

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	Species	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Pb	Austria	3	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-G._circellaris*	.	8928.00	1037	.	Rabitsch_1995a
Pb	Austria	4	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-P._fossor*	.	4665.00	57.8	.	Rabitsch_1995a
Pb	Austria	5	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-Q._fuliginosus*	.	574.00	11.3	.	Rabitsch_1995a
Zn	Austria	1	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-Q._fuliginosus*	.	1697.00	380	.	Rabitsch_1995a
Zn	Austria	1	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-P._fossor*	.	1697.00	635	.	Rabitsch_1995a
Zn	Austria	3	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-Z._humeralis*	.	7795.00	95.5	.	Rabitsch_1995a
Zn	Austria	3	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-P._fossor*	.	7795.00	472	.	Rabitsch_1995a
Zn	Austria	3	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-X._linearis*	.	7795.00	550	.	Rabitsch_1995a
Zn	Austria	3	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-G._circellaris*	.	7795.00	891	.	Rabitsch_1995a
Zn	Austria	4	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-P._fossor*	.	5813.00	589	.	Rabitsch_1995a
Zn	Austria	5	field	resident	predator	Insecta	Coleoptera	Staphylinidae	*staphylinidae-Q._fuliginosus*	.	329.00	314	.	Rabitsch_1995a
Cd	Austria	1	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Myrmica_sabuleti*	.	14.80	5.5	.	Rabitsch_1995b
Cd	Austria	1	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Formica_fusca*	.	14.80	14.9	.	Rabitsch_1995b
Cd	Austria	1	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Lasius_platythorax*	.	14.80	28.6	.	Rabitsch_1995b
Cd	Austria	1	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Myrmica_sabuleti*	.	14.80	4.3	.	Rabitsch_1995b
Cd	Austria	1	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Myrmica_sabuleti*	.	14.80	12.9	.	Rabitsch_1995b
Cd	Austria	2	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Tetramorium_caespitum*	.	96.90	3.7	.	Rabitsch_1995b
Cd	Austria	2	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Myrmica_sabuleti*	.	96.90	7.2	.	Rabitsch_1995b
Cd	Austria	3	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Lasius_platythorax*	.	29.60	6.6	.	Rabitsch_1995b
Cd	Austria	3	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Camponitus_ligniperda*	.	29.60	27.5	.	Rabitsch_1995b
Cd	Austria	3	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Leptohorax_acervorum*	.	29.60	5.7	.	Rabitsch_1995b
Cd	Austria	3	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Camponitus_ligniperda*	.	29.60	48.2	.	Rabitsch_1995b
Cd	Austria	4	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Myrmica_sabuleti*	.	24.30	3.6	.	Rabitsch_1995b
Cd	Austria	4	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Myrmica_sabuleti*	.	24.30	9.5	.	Rabitsch_1995b
Cd	Austria	4	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Tapinoma_ambigumm*	.	24.30	16.7	.	Rabitsch_1995b
Cd	Austria	5	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Camponitus_vagus*	.	2.00	25.1	.	Rabitsch_1995b
Cd	Austria	5	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Lasius_platythorax*	.	2.00	23.4	.	Rabitsch_1995b
Cd	Austria	5	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Camponitus_ligniperda*	.	2.00	45.5	.	Rabitsch_1995b
Cu	Austria	1	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Formica_fusca*	.	94.60	18.7	.	Rabitsch_1995b
Cu	Austria	1	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Myrmica_sabuleti*	.	94.60	21.4	.	Rabitsch_1995b
Cu	Austria	1	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Lasius_platythorax*	.	94.60	44.8	.	Rabitsch_1995b
Cu	Austria	1	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Myrmica_sabuleti*	.	94.60	12.6	.	Rabitsch_1995b
Cu	Austria	1	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Myrmica_sabuleti*	.	94.60	15.8	.	Rabitsch_1995b
Cu	Austria	2	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Tetramorium_caespitum*	.	1319.60	47.1	.	Rabitsch_1995b
Cu	Austria	2	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Myrmica_sabuleti*	.	1319.60	14.9	.	Rabitsch_1995b
Cu	Austria	3	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Lasius_platythorax*	.	183.90	8.8	.	Rabitsch_1995b
Cu	Austria	3	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Camponitus_ligniperda*	.	183.90	14.7	.	Rabitsch_1995b
Cu	Austria	3	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Leptohorax_acervorum*	.	183.90	5.2	.	Rabitsch_1995b
Cu	Austria	3	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Camponitus_ligniperda*	.	183.90	37.2	.	Rabitsch_1995b
Cu	Austria	4	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Myrmica_sabuleti*	.	85.50	12.8	.	Rabitsch_1995b
Cu	Austria	4	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Myrmica_sabuleti*	.	85.50	15.5	.	Rabitsch_1995b
Cu	Austria	4	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Tapinoma_ambigumm*	.	85.50	40.1	.	Rabitsch_1995b
Cu	Austria	5	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Camponitus_vagus*	.	34.90	38.6	.	Rabitsch_1995b
Cu	Austria	5	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Lasius_platythorax*	.	34.90	8.6	.	Rabitsch_1995b
Cu	Austria	5	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Camponitus_ligniperda*	.	34.90	21.5	.	Rabitsch_1995b
Pb	Austria	1	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Myrmica_sabuleti*	.	1190.00	15.3	.	Rabitsch_1995b
Pb	Austria	1	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Lasius_platythorax*	.	1190.00	57.8	.	Rabitsch_1995b
Pb	Austria	1	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Formica_fusca*	.	1190.00	67.7	.	Rabitsch_1995b
Pb	Austria	1	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Myrmica_sabuleti*	.	1190.00	17.9	.	Rabitsch_1995b
Pb	Austria	1	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Myrmica_sabuleti*	.	1190.00	19.5	.	Rabitsch_1995b
Pb	Austria	2	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Tetramorium_caespitum*	.	61946.00	2273	.	Rabitsch_1995b
Pb	Austria	2	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Myrmica_sabuleti*	.	61946.00	147.8	.	Rabitsch_1995b
Pb	Austria	3	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Lasius_platythorax*	.	6788.00	38.7	.	Rabitsch_1995b
Pb	Austria	3	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Camponitus_ligniperda*	.	6788.00	170.8	.	Rabitsch_1995b

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	Species	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Pb	Austria	3	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Leptohorax_acervorum*	.	6788.00	102.2	.	Rabitsch_1995b
Pb	Austria	3	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Camponitus_ligniperda*	.	6788.00	375.8	.	Rabitsch_1995b
Pb	Austria	4	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Myrmica_sabuleti*	.	4667.00	33.2	.	Rabitsch_1995b
Pb	Austria	4	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Myrmica_sabuleti*	.	4667.00	44.2	.	Rabitsch_1995b
Pb	Austria	4	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Tapinoma_ambigumm*	.	4667.00	239.9	.	Rabitsch_1995b
Pb	Austria	5	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Camponitus_vagus*	.	516.00	58.7	.	Rabitsch_1995b
Pb	Austria	5	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Lasius_platythorax*	.	516.00	9.9	.	Rabitsch_1995b
Pb	Austria	5	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Camponitus_ligniperda*	.	516.00	90.6	.	Rabitsch_1995b
Zn	Austria	1	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Myrmica_sabuleti*	.	1237.00	200	.	Rabitsch_1995b
Zn	Austria	1	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Lasius_platythorax*	.	1237.00	276	.	Rabitsch_1995b
Zn	Austria	1	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Formica_fusca*	.	1237.00	545	.	Rabitsch_1995b
Zn	Austria	1	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Myrmica_sabuleti*	.	1237.00	140	.	Rabitsch_1995b
Zn	Austria	1	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Myrmica_sabuleti*	.	1237.00	158	.	Rabitsch_1995b
Zn	Austria	2	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Tetramorium_caespitum*	.	6672.00	211	.	Rabitsch_1995b
Zn	Austria	2	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Myrmica_sabuleti*	.	6672.00	435	.	Rabitsch_1995b
Zn	Austria	3	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Lasius_platythorax*	.	3964.00	439	.	Rabitsch_1995b
Zn	Austria	3	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Camponitus_ligniperda*	.	3964.00	739	.	Rabitsch_1995b
Zn	Austria	3	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Leptohorax_acervorum*	.	3964.00	232	.	Rabitsch_1995b
Zn	Austria	3	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Camponitus_ligniperda*	.	3964.00	3011	.	Rabitsch_1995b
Zn	Austria	4	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Myrmica_sabuleti*	.	3058.00	224	.	Rabitsch_1995b
Zn	Austria	4	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Myrmica_sabuleti*	.	3058.00	334	.	Rabitsch_1995b
Zn	Austria	4	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Tapinoma_ambigumm*	.	3058.00	950	.	Rabitsch_1995b
Zn	Austria	5	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Camponitus_vagus*	.	291.00	1286	.	Rabitsch_1995b
Zn	Austria	5	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Lasius_platythorax*	.	291.00	239	.	Rabitsch_1995b
Zn	Austria	5	field	resident	predator	Insecta	Hymenoptera	Formicidae	*Camponitus_ligniperda*	.	291.00	964	.	Rabitsch_1995b
Cd	Austria	1	field	resident	predator	Arachinida	Araneae	.	*Harpactea_lepida*	.	14.80	43.2	.	Rabitsch_1995c
Cd	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Gonatium_rubidium*	.	96.90	15.3	.	Rabitsch_1995c
Cd	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Micaria_fulgens*	.	96.90	72.5	.	Rabitsch_1995c
Cd	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Zodarion_rubidum*	.	96.90	30.5	.	Rabitsch_1995c
Cd	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Zelotes_electus*	.	96.90	41.9	.	Rabitsch_1995c
Cd	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Micaria_fulgens*	.	96.90	99.6	.	Rabitsch_1995c
Cd	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Alopecosa_trabalis*	.	96.90	41.5	.	Rabitsch_1995c
Cd	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Alopecosa_trabalis*	.	96.90	56.1	.	Rabitsch_1995c
Cd	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Phrurolithus_festivis*	.	96.90	82.4	.	Rabitsch_1995c
Cd	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Xerolycosa_nemoralis*	.	96.90	50.1	.	Rabitsch_1995c
Cd	Austria	3	field	resident	predator	Arachinida	Araneae	.	*Zelotes_apricorum*	.	29.60	60.2	.	Rabitsch_1995c
Cd	Austria	3	field	resident	predator	Arachinida	Araneae	.	*Hahnia_ononidum*	.	29.60	56.5	.	Rabitsch_1995c
Cd	Austria	3	field	resident	predator	Arachinida	Araneae	.	*Hahnia_ononidum*	.	29.60	29.7	.	Rabitsch_1995c
Cd	Austria	3	field	resident	predator	Arachinida	Araneae	.	*Pardosa_luubris_s._Str.*	.	29.60	74.9	.	Rabitsch_1995c
Cd	Austria	3	field	resident	predator	Arachinida	Araneae	.	*Pardosa_alacris*	.	29.60	90.7	.	Rabitsch_1995c
Cd	Austria	4	field	resident	predator	Arachinida	Araneae	.	*Alopecosa_cuneata*	.	24.30	90.5	.	Rabitsch_1995c
Cd	Austria	4	field	resident	predator	Arachinida	Araneae	.	*Alopecosa_trabalis*	.	24.30	43	.	Rabitsch_1995c
Cd	Austria	4	field	resident	predator	Arachinida	Araneae	.	*Alopecosa_trabalis*	.	24.30	47.8	.	Rabitsch_1995c
Cd	Austria	5	field	resident	predator	Arachinida	Araneae	.	*Macrargus_rufus*	.	2.00	29.6	.	Rabitsch_1995c
Cd	Austria	5	field	resident	predator	Arachinida	Araneae	.	*Macrargus_rufus*	.	2.00	28.8	.	Rabitsch_1995c
Cd	Austria	5	field	resident	predator	Arachinida	Araneae	.	*Histopona_torpida*	.	2.00	30.3	.	Rabitsch_1995c
Cd	Austria	5	field	resident	predator	Arachinida	Araneae	.	*Amaurobius_obustus*	.	2.00	54.3	.	Rabitsch_1995c
Cu	Austria	1	field	resident	predator	Arachinida	Araneae	.	*Harpactea_lepida*	.	94.60	81.8	.	Rabitsch_1995c
Cu	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Gonatium_rubidium*	.	1319.60	37.3	.	Rabitsch_1995c
Cu	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Micaria_fulgens*	.	1319.60	95.2	.	Rabitsch_1995c
Cu	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Zodarion_rubidum*	.	1319.60	51.9	.	Rabitsch_1995c
Cu	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Zelotes_electus*	.	1319.60	107	.	Rabitsch_1995c
Cu	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Micaria_fulgens*	.	1319.60	110.2	.	Rabitsch_1995c
Cu	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Alopecosa_trabalis*	.	1319.60	147.2	.	Rabitsch_1995c

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	Species	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Cu	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Alopecosa_trabalis*	.	1319.60	192.5	.	Rabitsch_1995c
Cu	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Phrurolithus_festivis*	.	1319.60	113	.	Rabitsch_1995c
Cu	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Xerolycosa_nemoralis*	.	1319.60	94.6	.	Rabitsch_1995c
Cu	Austria	3	field	resident	predator	Arachinida	Araneae	.	*Zelotes_apricorum*	.	183.90	291.5	.	Rabitsch_1995c
Cu	Austria	3	field	resident	predator	Arachinida	Araneae	.	*Hahnia_ononidum*	.	183.90	66.6	.	Rabitsch_1995c
Cu	Austria	3	field	resident	predator	Arachinida	Araneae	.	*Hahnia_ononidum*	.	183.90	61.3	.	Rabitsch_1995c
Cu	Austria	3	field	resident	predator	Arachinida	Araneae	.	*Pardosa_luubris_s._Str.*	.	183.90	174.4	.	Rabitsch_1995c
Cu	Austria	3	field	resident	predator	Arachinida	Araneae	.	*Pardosa_alacris*	.	183.90	254.7	.	Rabitsch_1995c
Cu	Austria	4	field	resident	predator	Arachinida	Araneae	.	*Alopecosa_cuneata*	.	85.50	149.8	.	Rabitsch_1995c
Cu	Austria	4	field	resident	predator	Arachinida	Araneae	.	*Alopecosa_trabalis*	.	85.50	127.4	.	Rabitsch_1995c
Cu	Austria	4	field	resident	predator	Arachinida	Araneae	.	*Alopecosa_trabalis*	.	85.50	154.9	.	Rabitsch_1995c
Cu	Austria	5	field	resident	predator	Arachinida	Araneae	.	*Macrargus_rufus*	.	34.90	48.6	.	Rabitsch_1995c
Cu	Austria	5	field	resident	predator	Arachinida	Araneae	.	*Macrargus_rufus*	.	34.90	67.1	.	Rabitsch_1995c
Cu	Austria	5	field	resident	predator	Arachinida	Araneae	.	*Histopona_torpida*	.	34.90	152.8	.	Rabitsch_1995c
Cu	Austria	5	field	resident	predator	Arachinida	Araneae	.	*Amaurobius_obustus*	.	34.90	158.7	.	Rabitsch_1995c
Pb	Austria	1	field	resident	predator	Arachinida	Araneae	.	*Harpactea_lepida*	.	1190.00	33.7	.	Rabitsch_1995c
Pb	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Micaria_fulgens*	.	61946.00	337	.	Rabitsch_1995c
Pb	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Gonatium_rubidium*	.	61946.00	530	.	Rabitsch_1995c
Pb	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Zodarion_rubidum*	.	61946.00	438	.	Rabitsch_1995c
Pb	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Zelotes_electus*	.	61946.00	457	.	Rabitsch_1995c
Pb	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Micaria_fulgens*	.	61946.00	642	.	Rabitsch_1995c
Pb	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Alopecosa_trabalis*	.	61946.00	160	.	Rabitsch_1995c
Pb	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Alopecosa_trabalis*	.	61946.00	216	.	Rabitsch_1995c
Pb	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Phrurolithus_festivis*	.	61946.00	1221	.	Rabitsch_1995c
Pb	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Xerolycosa_nemoralis*	.	61946.00	359	.	Rabitsch_1995c
Pb	Austria	3	field	resident	predator	Arachinida	Araneae	.	*Zelotes_apricorum*	.	6788.00	40.5	.	Rabitsch_1995c
Pb	Austria	3	field	resident	predator	Arachinida	Araneae	.	*Hahnia_ononidum*	.	6788.00	188	.	Rabitsch_1995c
Pb	Austria	3	field	resident	predator	Arachinida	Araneae	.	*Pardosa_luubris_s._Str.*	.	6788.00	83.4	.	Rabitsch_1995c
Pb	Austria	3	field	resident	predator	Arachinida	Araneae	.	*Pardosa_alacris*	.	6788.00	83.9	.	Rabitsch_1995c
Pb	Austria	3	field	resident	predator	Arachinida	Araneae	.	*Hahnia_ononidum*	.	6788.00	207	.	Rabitsch_1995c
Pb	Austria	4	field	resident	predator	Arachinida	Araneae	.	*Alopecosa_cuneata*	.	4667.00	66.1	.	Rabitsch_1995c
Pb	Austria	4	field	resident	predator	Arachinida	Araneae	.	*Alopecosa_trabalis*	.	4667.00	25.6	.	Rabitsch_1995c
Pb	Austria	4	field	resident	predator	Arachinida	Araneae	.	*Alopecosa_trabalis*	.	4667.00	26.5	.	Rabitsch_1995c
Pb	Austria	5	field	resident	predator	Arachinida	Araneae	.	*Macrargus_rufus*	.	516.00	67.8	.	Rabitsch_1995c
Pb	Austria	5	field	resident	predator	Arachinida	Araneae	.	*Macrargus_rufus*	.	516.00	104	.	Rabitsch_1995c
Pb	Austria	5	field	resident	predator	Arachinida	Araneae	.	*Histopona_torpida*	.	516.00	6.9	.	Rabitsch_1995c
Pb	Austria	5	field	resident	predator	Arachinida	Araneae	.	*Amaurobius_obustus*	.	516.00	23.4	.	Rabitsch_1995c
Zn	Austria	1	field	resident	predator	Arachinida	Araneae	.	*Harpactea_lepida*	.	1237.00	1273	.	Rabitsch_1995c
Zn	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Micaria_fulgens*	.	6672.00	792	.	Rabitsch_1995c
Zn	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Gonatium_rubidium*	.	6672.00	980	.	Rabitsch_1995c
Zn	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Zodarion_rubidum*	.	6672.00	740	.	Rabitsch_1995c
Zn	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Zelotes_electus*	.	6672.00	841	.	Rabitsch_1995c
Zn	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Micaria_fulgens*	.	6672.00	931	.	Rabitsch_1995c
Zn	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Alopecosa_trabalis*	.	6672.00	1721	.	Rabitsch_1995c
Zn	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Alopecosa_trabalis*	.	6672.00	2024	.	Rabitsch_1995c
Zn	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Phrurolithus_festivis*	.	6672.00	1054	.	Rabitsch_1995c
Zn	Austria	2	field	resident	predator	Arachinida	Araneae	.	*Xerolycosa_nemoralis*	.	6672.00	1732	.	Rabitsch_1995c
Zn	Austria	3	field	resident	predator	Arachinida	Araneae	.	*Zelotes_apricorum*	.	3964.00	1411	.	Rabitsch_1995c
Zn	Austria	3	field	resident	predator	Arachinida	Araneae	.	*Hahnia_ononidum*	.	3964.00	786	.	Rabitsch_1995c
Zn	Austria	3	field	resident	predator	Arachinida	Araneae	.	*Hahnia_ononidum*	.	3964.00	751	.	Rabitsch_1995c
Zn	Austria	3	field	resident	predator	Arachinida	Araneae	.	*Pardosa_luubris_s._Str.*	.	3964.00	1148	.	Rabitsch_1995c
Zn	Austria	3	field	resident	predator	Arachinida	Araneae	.	*Pardosa_alacris*	.	3964.00	1413	.	Rabitsch_1995c
Zn	Austria	4	field	resident	predator	Arachinida	Araneae	.	*Alopecosa_cuneata*	.	3058.00	1308	.	Rabitsch_1995c
Zn	Austria	4	field	resident	predator	Arachinida	Araneae	.	*Alopecosa_trabalis*	.	3058.00	1120	.	Rabitsch_1995c

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	Species	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Zn	Austria	4	field	resident	predator	Arachinida	Araneae	.	Alopecosa_trabalis	.	3058.00	1160	.	Rabitsch_1995c
Zn	Austria	5	field	resident	predator	Arachinida	Araneae	.	Macrargus_rufus	.	291.00	458	.	Rabitsch_1995c
Zn	Austria	5	field	resident	predator	Arachinida	Araneae	.	Macrargus_rufus	.	291.00	386	.	Rabitsch_1995c
Zn	Austria	5	field	resident	predator	Arachinida	Araneae	.	Histopona_torpida	.	291.00	621	.	Rabitsch_1995c
Zn	Austria	5	field	resident	predator	Arachinida	Araneae	.	Amaurobius_obustus	.	291.00	960	.	Rabitsch_1995c
Cd	Austria	1	field	resident	predator	Arachinida	Opiliones	Opilionidae	Phalangium_opilio	.	14.80	59.8	.	Rabitsch_1995c
Cd	Austria	1	field	resident	predator	Arachinida	Opiliones	Opilionidae	Paranemastoma_4-punctatum	.	14.80	30.9	.	Rabitsch_1995c
Cd	Austria	1	field	resident	predator	Arachinida	Opiliones	Opilionidae	Oliolophus_tridens	.	14.80	63.9	.	Rabitsch_1995c
Cd	Austria	1	field	resident	predator	Arachinida	Opiliones	Opilionidae	Oliolophus_tridens	.	14.80	43.2	.	Rabitsch_1995c
Cd	Austria	5	field	resident	predator	Arachinida	Opiliones	Opilionidae	Lacinius_ephippiatus	.	2.00	16.8	.	Rabitsch_1995c
Cd	Austria	5	field	resident	predator	Arachinida	Opiliones	Opilionidae	Nelima_semproni	.	2.00	21.6	.	Rabitsch_1995c
Cd	Austria	5	field	resident	predator	Arachinida	Opiliones	Opilionidae	Paranemastoma_4-punctatum	.	2.00	16.5	.	Rabitsch_1995c
Cd	Austria	5	field	resident	predator	Arachinida	Opiliones	Opilionidae	Lophopilio_palpinalis	.	2.00	54.7	.	Rabitsch_1995c
Cd	Austria	5	field	resident	predator	Arachinida	Opiliones	Opilionidae	Lophopilio_palpinalis	.	2.00	37.4	.	Rabitsch_1995c
Cu	Austria	1	field	resident	predator	Arachinida	Opiliones	Opilionidae	Phalangium_opilio	.	94.60	39.4	.	Rabitsch_1995c
Cu	Austria	1	field	resident	predator	Arachinida	Opiliones	Opilionidae	Paranemastoma_4-punctatum	.	94.60	41.3	.	Rabitsch_1995c
Cu	Austria	1	field	resident	predator	Arachinida	Opiliones	Opilionidae	Oliolophus_tridens	.	94.60	36.7	.	Rabitsch_1995c
Cu	Austria	1	field	resident	predator	Arachinida	Opiliones	Opilionidae	Oliolophus_tridens	.	94.60	20.3	.	Rabitsch_1995c
Cu	Austria	5	field	resident	predator	Arachinida	Opiliones	Opilionidae	Lacinius_ephippiatus	.	34.90	49.4	.	Rabitsch_1995c
Cu	Austria	5	field	resident	predator	Arachinida	Opiliones	Opilionidae	Nelima_semproni	.	34.90	103.4	.	Rabitsch_1995c
Cu	Austria	5	field	resident	predator	Arachinida	Opiliones	Opilionidae	Paranemastoma_4-punctatum	.	34.90	23.6	.	Rabitsch_1995c
Cu	Austria	5	field	resident	predator	Arachinida	Opiliones	Opilionidae	Lophopilio_palpinalis	.	34.90	65.9	.	Rabitsch_1995c
Cu	Austria	5	field	resident	predator	Arachinida	Opiliones	Opilionidae	Lophopilio_palpinalis	.	34.90	41.9	.	Rabitsch_1995c
Pb	Austria	1	field	resident	predator	Arachinida	Opiliones	Opilionidae	Phalangium_opilio	.	1190.00	95.2	.	Rabitsch_1995c
Pb	Austria	1	field	resident	predator	Arachinida	Opiliones	Opilionidae	Paranemastoma_4-punctatum	.	1190.00	62	.	Rabitsch_1995c
Pb	Austria	1	field	resident	predator	Arachinida	Opiliones	Opilionidae	Oliolophus_tridens	.	1190.00	92.9	.	Rabitsch_1995c
Pb	Austria	1	field	resident	predator	Arachinida	Opiliones	Opilionidae	Oliolophus_tridens	.	1190.00	78.3	.	Rabitsch_1995c
Pb	Austria	5	field	resident	predator	Arachinida	Opiliones	Opilionidae	Lacinius_ephippiatus	.	516.00	46.6	.	Rabitsch_1995c
Pb	Austria	5	field	resident	predator	Arachinida	Opiliones	Opilionidae	Nelima_semproni	.	516.00	101.6	.	Rabitsch_1995c
Pb	Austria	5	field	resident	predator	Arachinida	Opiliones	Opilionidae	Paranemastoma_4-punctatum	.	516.00	28.5	.	Rabitsch_1995c
Pb	Austria	5	field	resident	predator	Arachinida	Opiliones	Opilionidae	Lophopilio_palpinalis	.	516.00	35.7	.	Rabitsch_1995c
Pb	Austria	5	field	resident	predator	Arachinida	Opiliones	Opilionidae	Lophopilio_palpinalis	.	516.00	36.9	.	Rabitsch_1995c
Zn	Austria	1	field	resident	predator	Arachinida	Opiliones	Opilionidae	Phalangium_opilio	.	1237.00	530	.	Rabitsch_1995c
Zn	Austria	1	field	resident	predator	Arachinida	Opiliones	Opilionidae	Paranemastoma_4-punctatum	.	1237.00	422	.	Rabitsch_1995c
Zn	Austria	1	field	resident	predator	Arachinida	Opiliones	Opilionidae	Oliolophus_tridens	.	1237.00	1242	.	Rabitsch_1995c
Zn	Austria	1	field	resident	predator	Arachinida	Opiliones	Opilionidae	Oliolophus_tridens	.	1237.00	588	.	Rabitsch_1995c
Zn	Austria	5	field	resident	predator	Arachinida	Opiliones	Opilionidae	Lacinius_ephippiatus	.	291.00	201	.	Rabitsch_1995c
Zn	Austria	5	field	resident	predator	Arachinida	Opiliones	Opilionidae	Nelima_semproni	.	291.00	184	.	Rabitsch_1995c
Zn	Austria	5	field	resident	predator	Arachinida	Opiliones	Opilionidae	Paranemastoma_4-punctatum	.	291.00	287	.	Rabitsch_1995c
Zn	Austria	5	field	resident	predator	Arachinida	Opiliones	Opilionidae	Lophopilio_palpinalis	.	291.00	666	.	Rabitsch_1995c
Zn	Austria	5	field	resident	predator	Arachinida	Opiliones	Opilionidae	Lophopilio_palpinalis	.	291.00	476	.	Rabitsch_1995c
As	Wyoming	Reference	field	resident	herbivore	Insecta	Orthoptera	Acrididae	Grasshoppers	.	3.57	0.12	.	Ramirez_and_Rogers_2000
As	Wyoming	Study_Area	field	resident	herbivore	Insecta	Orthoptera	Acrididae	Grasshoppers	.	3.96	0.09	.	Ramirez_and_Rogers_2000
Ba	Wyoming	Reference	field	resident	herbivore	Insecta	Orthoptera	Acrididae	Grasshoppers	.	76.99	3.07	.	Ramirez_and_Rogers_2000
Ba	Wyoming	Study_Area	field	resident	herbivore	Insecta	Orthoptera	Acrididae	Grasshoppers	.	113.80	2.10	.	Ramirez_and_Rogers_2000
Cd	Wyoming	Reference	field	resident	herbivore	Insecta	Orthoptera	Acrididae	Grasshoppers	.	0.21	0.28	.	Ramirez_and_Rogers_2000
Cd	Wyoming	Study_Area	field	resident	herbivore	Insecta	Orthoptera	Acrididae	Grasshoppers	.	0.09	0.40	.	Ramirez_and_Rogers_2000
Cu	Wyoming	Reference	field	resident	herbivore	Insecta	Orthoptera	Acrididae	Grasshoppers	.	0.01	28.97	.	Ramirez_and_Rogers_2000
Cu	Wyoming	Study_Area	field	resident	herbivore	Insecta	Orthoptera	Acrididae	Grasshoppers	.	15.50	37.17	.	Ramirez_and_Rogers_2000
Mg	Wyoming	Reference	field	resident	herbivore	Insecta	Orthoptera	Acrididae	Grasshoppers	.	4137.67	1177.07	.	Ramirez_and_Rogers_2000
Mg	Wyoming	Study_Area	field	resident	herbivore	Insecta	Orthoptera	Acrididae	Grasshoppers	.	3965.30	1233.47	.	Ramirez_and_Rogers_2000
Mn	Wyoming	Reference	field	resident	herbivore	Insecta	Orthoptera	Acrididae	Grasshoppers	.	13.16	11.34	.	Ramirez_and_Rogers_2000
Mn	Wyoming	Study_Area	field	resident	herbivore	Insecta	Orthoptera	Acrididae	Grasshoppers	.	212.90	32.42	.	Ramirez_and_Rogers_2000
Se	Wyoming	Reference	field	resident	herbivore	Insecta	Orthoptera	Acrididae	Grasshoppers	.	0.62	0.72	.	Ramirez_and_Rogers_2000

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	*Species*	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Se	Wyoming	Study_Area	field	resident	herbivore	Insecta	Orthoptera	Acrididae	Grasshoppers	.	3.09	12.82	.	Ramirez_and_Rogers_2000
V	Wyoming	Reference	field	resident	herbivore	Insecta	Orthoptera	Acrididae	Grasshoppers	.	20.76	0.58	.	Ramirez_and_Rogers_2000
Zn	Wyoming	Reference	field	resident	herbivore	Insecta	Orthoptera	Acrididae	Grasshoppers	.	59.31	140.50	.	Ramirez_and_Rogers_2000
Zn	Wyoming	Study_Area	field	resident	herbivore	Insecta	Orthoptera	Acrididae	Grasshoppers	.	51.10	139.93	.	Ramirez_and_Rogers_2000
Cd	Tennessee	east_Tennessee	field	resident	herbivore	Insecta	Orthoptera	Gryllidae	*P.fasciatus*	0.004	0.004	0.042	.	Van_Hook_and_Yates_1975
Cd	Tennessee	east_Tennessee	field	resident	predator	Arachinida	Araneae	.	*Lycosa_sp.*	0.004	0.004	0.03	.	Van_Hook_and_Yates_1975
Cd	Missouri	NE0.4	field	resident	detritivore	Insecta	.	.	.	.	128.82	8.9	.	Watson_et_al_1976
Cd	Missouri	NE0.8	field	resident	detritivore	Insecta	.	.	.	.	49.86	7.6	.	Watson_et_al_1976
Cd	Missouri	NE1.2	field	resident	detritivore	Insecta	.	.	.	.	62.06	35.9	.	Watson_et_al_1976
Cd	Missouri	NW0.4	field	resident	detritivore	Insecta	.	.	.	.	124.54	26.2	.	Watson_et_al_1976
Cd	Missouri	NW0.8	field	resident	detritivore	Insecta	.	.	.	.	42.97	9.3	.	Watson_et_al_1976
Cd	Missouri	NW1.2	field	resident	detritivore	Insecta	.	.	.	.	29.80	8.2	.	Watson_et_al_1976
Cd	Missouri	NW2.0	field	resident	detritivore	Insecta	.	.	.	.	15.36	4.8	.	Watson_et_al_1976
Cd	Missouri	W0.4	field	resident	detritivore	Insecta	.	.	.	.	96.64	17.6	.	Watson_et_al_1976
Cd	Missouri	W0.8	field	resident	detritivore	Insecta	.	.	.	.	34.94	4.2	.	Watson_et_al_1976
Cd	Missouri	W1.2	field	resident	detritivore	Insecta	.	.	.	.	20.10	9.5	.	Watson_et_al_1976
Cd	Missouri	W1.6	field	resident	detritivore	Insecta	.	.	.	.	15.85	3.6	.	Watson_et_al_1976
Cd	Missouri	W21.0_(reference)	field	resident	detritivore	Insecta	.	.	.	.	0.11	2.3	.	Watson_et_al_1976
Cu	Missouri	NE0.4	field	resident	detritivore	Insecta	.	.	.	.	12.20	122	.	Watson_et_al_1976
Cu	Missouri	NE0.8	field	resident	detritivore	Insecta	.	.	.	.	26.29	163	.	Watson_et_al_1976
Cu	Missouri	NE1.2	field	resident	detritivore	Insecta	.	.	.	.	35.08	1189.2	.	Watson_et_al_1976
Cu	Missouri	NW0.4	field	resident	detritivore	Insecta	.	.	.	.	9.55	476.2	.	Watson_et_al_1976
Cu	Missouri	NW0.8	field	resident	detritivore	Insecta	.	.	.	.	3.19	79.2	.	Watson_et_al_1976
Cu	Missouri	NW1.2	field	resident	detritivore	Insecta	.	.	.	.	1.60	512.8	.	Watson_et_al_1976
Cu	Missouri	NW2.0	field	resident	detritivore	Insecta	.	.	.	.	1.00	50.7	.	Watson_et_al_1976
Cu	Missouri	W0.4	field	resident	detritivore	Insecta	.	.	.	.	6.79	155.9	.	Watson_et_al_1976
Cu	Missouri	W0.8	field	resident	detritivore	Insecta	.	.	.	.	1.93	204.1	.	Watson_et_al_1976
Cu	Missouri	W1.2	field	resident	detritivore	Insecta	.	.	.	.	1.17	54.9	.	Watson_et_al_1976
Cu	Missouri	W1.6	field	resident	detritivore	Insecta	.	.	.	.	0.96	13.3	.	Watson_et_al_1976
Cu	Missouri	W21.0_(reference)	field	resident	detritivore	Insecta	.	.	.	.	0.19	24.1	.	Watson_et_al_1976
Pb	Missouri	NE0.4	field	resident	detritivore	Insecta	.	.	.	.	55.12	1382.1	.	Watson_et_al_1976
Pb	Missouri	NE0.8	field	resident	detritivore	Insecta	.	.	.	.	22.39	282.6	.	Watson_et_al_1976
Pb	Missouri	NE1.2	field	resident	detritivore	Insecta	.	.	.	.	30.57	16637.7	.	Watson_et_al_1976
Pb	Missouri	NW0.4	field	resident	detritivore	Insecta	.	.	.	.	60.52	4523.8	.	Watson_et_al_1976
Pb	Missouri	NW0.8	field	resident	detritivore	Insecta	.	.	.	.	20.39	769.2	.	Watson_et_al_1976
Pb	Missouri	NW1.2	field	resident	detritivore	Insecta	.	.	.	.	9.91	333.3	.	Watson_et_al_1976
Pb	Missouri	NW2.0	field	resident	detritivore	Insecta	.	.	.	.	5.33	202.6	.	Watson_et_al_1976
Pb	Missouri	W0.4	field	resident	detritivore	Insecta	.	.	.	.	51.22	1000	.	Watson_et_al_1976
Pb	Missouri	W0.8	field	resident	detritivore	Insecta	.	.	.	.	12.60	989.8	.	Watson_et_al_1976
Pb	Missouri	W1.2	field	resident	detritivore	Insecta	.	.	.	.	6.84	1027.9	.	Watson_et_al_1976
Pb	Missouri	W1.6	field	resident	detritivore	Insecta	.	.	.	.	4.63	217.6	.	Watson_et_al_1976
Pb	Missouri	W21.0_(reference)	field	resident	detritivore	Insecta	.	.	.	.	0.32	33.9	.	Watson_et_al_1976
Zn	Missouri	NE0.4	field	resident	detritivore	Insecta	.	.	.	.	24.82	268.3	.	Watson_et_al_1976
Zn	Missouri	NE0.8	field	resident	detritivore	Insecta	.	.	.	.	15.03	304.4	.	Watson_et_al_1976
Zn	Missouri	NE1.2	field	resident	detritivore	Insecta	.	.	.	.	25.60	813.1	.	Watson_et_al_1976
Zn	Missouri	NW0.4	field	resident	detritivore	Insecta	.	.	.	.	18.30	1428.6	.	Watson_et_al_1976
Zn	Missouri	NW0.8	field	resident	detritivore	Insecta	.	.	.	.	6.98	384.6	.	Watson_et_al_1976
Zn	Missouri	NW1.2	field	resident	detritivore	Insecta	.	.	.	.	4.56	897.4	.	Watson_et_al_1976
Zn	Missouri	NW2.0	field	resident	detritivore	Insecta	.	.	.	.	2.71	253.3	.	Watson_et_al_1976
Zn	Missouri	W0.4	field	resident	detritivore	Insecta	.	.	.	.	14.68	1117.7	.	Watson_et_al_1976
Zn	Missouri	W0.8	field	resident	detritivore	Insecta	.	.	.	.	5.05	224.5	.	Watson_et_al_1976
Zn	Missouri	W1.2	field	resident	detritivore	Insecta	.	.	.	.	3.11	238.3	.	Watson_et_al_1976
Zn	Missouri	W1.6	field	resident	detritivore	Insecta	.	.	.	.	2.41	102.4	.	Watson_et_al_1976
Zn	Missouri	W21.0_(reference)	field	resident	detritivore	Insecta	.	.	.	.	0.84	183.7	.	Watson_et_al_1976

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	Species	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Cd	Missouri	NE0.4	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	6.9	.	Watson_et_al_1976
Cd	Missouri	NE0.8	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	3	.	Watson_et_al_1976
Cd	Missouri	NE1.2	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	20.1	.	Watson_et_al_1976
Cd	Missouri	NW0.4	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	223.3	.	Watson_et_al_1976
Cd	Missouri	NW0.8	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	9.1	.	Watson_et_al_1976
Cd	Missouri	NW1.2	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	17.6	.	Watson_et_al_1976
Cd	Missouri	NW2.0	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	13.7	.	Watson_et_al_1976
Cd	Missouri	W0.4	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	125.7	.	Watson_et_al_1976
Cd	Missouri	W0.8	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	7.3	.	Watson_et_al_1976
Cd	Missouri	W1.2	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	15.1	.	Watson_et_al_1976
Cd	Missouri	W1.6	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	20.7	.	Watson_et_al_1976
Cd	Missouri	W21.0_(reference)	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	3	.	Watson_et_al_1976
Cu	Missouri	NE0.4	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	63.8	.	Watson_et_al_1976
Cu	Missouri	NE0.8	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	275.9	.	Watson_et_al_1976
Cu	Missouri	NE1.2	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	479.5	.	Watson_et_al_1976
Cu	Missouri	NW0.4	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	291.3	.	Watson_et_al_1976
Cu	Missouri	NW0.8	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	72.1	.	Watson_et_al_1976
Cu	Missouri	NW1.2	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	302.2	.	Watson_et_al_1976
Cu	Missouri	NW2.0	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	101.5	.	Watson_et_al_1976
Cu	Missouri	W0.4	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	137.1	.	Watson_et_al_1976
Cu	Missouri	W0.8	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	86.4	.	Watson_et_al_1976
Cu	Missouri	W1.2	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	42.5	.	Watson_et_al_1976
Cu	Missouri	W1.6	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	200	.	Watson_et_al_1976
Cu	Missouri	W21.0_(reference)	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	109.3	.	Watson_et_al_1976
Pb	Missouri	NE0.4	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	262.5	.	Watson_et_al_1976
Pb	Missouri	NE0.8	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	579.3	.	Watson_et_al_1976
Pb	Missouri	NE1.2	field	resident	detritivore	Insecta	.	.	litter-grazer	.	30.57	5479.5	.	Watson_et_al_1976
Pb	Missouri	NW0.4	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	12427.2	.	Watson_et_al_1976
Pb	Missouri	NW0.8	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	588.2	.	Watson_et_al_1976
Pb	Missouri	NW1.2	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	346.2	.	Watson_et_al_1976
Pb	Missouri	NW2.0	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	200.5	.	Watson_et_al_1976
Pb	Missouri	W0.4	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	485.7	.	Watson_et_al_1976
Pb	Missouri	W0.8	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	431.8	.	Watson_et_al_1976
Pb	Missouri	W1.2	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	1930.8	.	Watson_et_al_1976
Pb	Missouri	W1.6	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	500	.	Watson_et_al_1976
Pb	Missouri	W21.0_(reference)	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	136.6	.	Watson_et_al_1976
Zn	Missouri	NE0.4	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	300	.	Watson_et_al_1976
Zn	Missouri	NE0.8	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	220.7	.	Watson_et_al_1976
Zn	Missouri	NE1.2	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	456.6	.	Watson_et_al_1976
Zn	Missouri	NW0.4	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	310.7	.	Watson_et_al_1976
Zn	Missouri	NW0.8	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	294.1	.	Watson_et_al_1976
Zn	Missouri	NW1.2	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	285.7	.	Watson_et_al_1976
Zn	Missouri	NW2.0	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	1649.8	.	Watson_et_al_1976
Zn	Missouri	W0.4	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	1571.4	.	Watson_et_al_1976
Zn	Missouri	W0.8	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	136.4	.	Watson_et_al_1976
Zn	Missouri	W1.2	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	222.3	.	Watson_et_al_1976
Zn	Missouri	W1.6	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	1785.7	.	Watson_et_al_1976
Zn	Missouri	W21.0_(reference)	field	resident	detritivore	Insecta	.	.	litter-grazer	.	.	273.2	.	Watson_et_al_1976
Cd	Missouri	NE0.4	field	resident	fungivore	Insecta	.	.	.	.	128.82	21	.	Watson_et_al_1976
Cd	Missouri	NE0.8	field	resident	fungivore	Insecta	.	.	.	.	49.86	5.2	.	Watson_et_al_1976
Cd	Missouri	NE1.2	field	resident	fungivore	Insecta	.	.	.	.	62.06	31.5	.	Watson_et_al_1976
Cd	Missouri	NW0.4	field	resident	fungivore	Insecta	.	.	.	.	124.54	10.8	.	Watson_et_al_1976
Cd	Missouri	NW0.8	field	resident	fungivore	Insecta	.	.	.	.	42.97	37.1	.	Watson_et_al_1976
Cd	Missouri	NW1.2	field	resident	fungivore	Insecta	.	.	.	.	29.80	7.8	.	Watson_et_al_1976

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	*Species*	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Cd	Missouri	NW2.0	field	resident	fungivore	Insecta	.	.	.	.	15.36	20.7	.	Watson_et_al_1976
Cd	Missouri	W0.4	field	resident	fungivore	Insecta	.	.	.	.	96.64	10.6	.	Watson_et_al_1976
Cd	Missouri	W0.8	field	resident	fungivore	Insecta	.	.	.	.	34.94	10.4	.	Watson_et_al_1976
Cd	Missouri	W1.2	field	resident	fungivore	Insecta	.	.	.	.	20.10	5.5	.	Watson_et_al_1976
Cd	Missouri	W1.6	field	resident	fungivore	Insecta	.	.	.	.	15.85	4.1	.	Watson_et_al_1976
Cd	Missouri	W21.0_(reference)	field	resident	fungivore	Insecta	.	.	.	.	0.11	1.4	.	Watson_et_al_1976
Cu	Missouri	NE0.4	field	resident	fungivore	Insecta	.	.	.	.	12.20	200	.	Watson_et_al_1976
Cu	Missouri	NE0.8	field	resident	fungivore	Insecta	.	.	.	.	26.29	137.9	.	Watson_et_al_1976
Cu	Missouri	NE1.2	field	resident	fungivore	Insecta	.	.	.	.	35.08	500	.	Watson_et_al_1976
Cu	Missouri	NW0.4	field	resident	fungivore	Insecta	.	.	.	.	9.55	71.7	.	Watson_et_al_1976
Cu	Missouri	NW0.8	field	resident	fungivore	Insecta	.	.	.	.	3.19	220	.	Watson_et_al_1976
Cu	Missouri	NW1.2	field	resident	fungivore	Insecta	.	.	.	.	1.60	140.2	.	Watson_et_al_1976
Cu	Missouri	NW2.0	field	resident	fungivore	Insecta	.	.	.	.	1.00	172.4	.	Watson_et_al_1976
Cu	Missouri	W0.4	field	resident	fungivore	Insecta	.	.	.	.	6.79	200	.	Watson_et_al_1976
Cu	Missouri	W0.8	field	resident	fungivore	Insecta	.	.	.	.	1.93	555.6	.	Watson_et_al_1976
Cu	Missouri	W1.2	field	resident	fungivore	Insecta	.	.	.	.	1.17	47.6	.	Watson_et_al_1976
Cu	Missouri	W1.6	field	resident	fungivore	Insecta	.	.	.	.	0.96	75	.	Watson_et_al_1976
Cu	Missouri	W21.0_(reference)	field	resident	fungivore	Insecta	.	.	.	.	0.19	149.3	.	Watson_et_al_1976
Pb	Missouri	NE0.4	field	resident	fungivore	Insecta	.	.	.	.	55.12	3100	.	Watson_et_al_1976
Pb	Missouri	NE0.8	field	resident	fungivore	Insecta	.	.	.	.	22.39	103.4	.	Watson_et_al_1976
Pb	Missouri	NE1.2	field	resident	fungivore	Insecta	.	.	.	.	30.57	450	.	Watson_et_al_1976
Pb	Missouri	NW0.4	field	resident	fungivore	Insecta	.	.	.	.	60.52	886.8	.	Watson_et_al_1976
Pb	Missouri	NW0.8	field	resident	fungivore	Insecta	.	.	.	.	20.39	2142.9	.	Watson_et_al_1976
Pb	Missouri	NW1.2	field	resident	fungivore	Insecta	.	.	.	.	9.91	579.4	.	Watson_et_al_1976
Pb	Missouri	NW2.0	field	resident	fungivore	Insecta	.	.	.	.	5.33	1046	.	Watson_et_al_1976
Pb	Missouri	W0.4	field	resident	fungivore	Insecta	.	.	.	.	51.22	388.9	.	Watson_et_al_1976
Pb	Missouri	W0.8	field	resident	fungivore	Insecta	.	.	.	.	12.60	407.4	.	Watson_et_al_1976
Pb	Missouri	W1.2	field	resident	fungivore	Insecta	.	.	.	.	6.84	104.8	.	Watson_et_al_1976
Pb	Missouri	W1.6	field	resident	fungivore	Insecta	.	.	.	.	4.63	156.2	.	Watson_et_al_1976
Pb	Missouri	W21.0_(reference)	field	resident	fungivore	Insecta	.	.	.	.	0.32	14.9	.	Watson_et_al_1976
Zn	Missouri	NE0.4	field	resident	fungivore	Insecta	.	.	.	.	24.82	400	.	Watson_et_al_1976
Zn	Missouri	NE0.8	field	resident	fungivore	Insecta	.	.	.	.	15.03	551.7	.	Watson_et_al_1976
Zn	Missouri	NE1.2	field	resident	fungivore	Insecta	.	.	.	.	25.60	1250	.	Watson_et_al_1976
Zn	Missouri	NW0.4	field	resident	fungivore	Insecta	.	.	.	.	18.30	301.9	.	Watson_et_al_1976
Zn	Missouri	NW0.8	field	resident	fungivore	Insecta	.	.	.	.	6.98	457.1	.	Watson_et_al_1976
Zn	Missouri	NW1.2	field	resident	fungivore	Insecta	.	.	.	.	4.56	355.1	.	Watson_et_al_1976
Zn	Missouri	NW2.0	field	resident	fungivore	Insecta	.	.	.	.	2.71	482.8	.	Watson_et_al_1976
Zn	Missouri	W0.4	field	resident	fungivore	Insecta	.	.	.	.	14.68	555.6	.	Watson_et_al_1976
Zn	Missouri	W0.8	field	resident	fungivore	Insecta	.	.	.	.	5.05	1333.3	.	Watson_et_al_1976
Zn	Missouri	W1.2	field	resident	fungivore	Insecta	.	.	.	.	3.11	342.9	.	Watson_et_al_1976
Zn	Missouri	W1.6	field	resident	fungivore	Insecta	.	.	.	.	2.41	375	.	Watson_et_al_1976
Zn	Missouri	W21.0_(reference)	field	resident	fungivore	Insecta	.	.	.	.	0.84	238.8	.	Watson_et_al_1976
Cd	Missouri	NE0.4	field	resident	omnivore	Insecta	.	.	.	.	128.82	68.4	.	Watson_et_al_1976
Cd	Missouri	NE0.8	field	resident	omnivore	Insecta	.	.	.	.	49.86	8.2	.	Watson_et_al_1976
Cd	Missouri	NE1.2	field	resident	omnivore	Insecta	.	.	.	.	62.06	12.6	.	Watson_et_al_1976
Cd	Missouri	NW0.4	field	resident	omnivore	Insecta	.	.	.	.	124.54	53.2	.	Watson_et_al_1976
Cd	Missouri	NW0.8	field	resident	omnivore	Insecta	.	.	.	.	42.97	24.6	.	Watson_et_al_1976
Cd	Missouri	NW1.2	field	resident	omnivore	Insecta	.	.	.	.	29.80	6.7	.	Watson_et_al_1976
Cd	Missouri	NW2.0	field	resident	omnivore	Insecta	.	.	.	.	15.36	12.7	.	Watson_et_al_1976
Cd	Missouri	W0.4	field	resident	omnivore	Insecta	.	.	.	.	96.64	207.4	.	Watson_et_al_1976
Cd	Missouri	W0.8	field	resident	omnivore	Insecta	.	.	.	.	34.94	11.4	.	Watson_et_al_1976
Cd	Missouri	W1.2	field	resident	omnivore	Insecta	.	.	.	.	20.10	19.3	.	Watson_et_al_1976
Cd	Missouri	W1.6	field	resident	omnivore	Insecta	.	.	.	.	15.85	10.8	.	Watson_et_al_1976
Cd	Missouri	W21.0_(reference)	field	resident	omnivore	Insecta	.	.	.	.	0.11	10.2	.	Watson_et_al_1976

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	*Species*	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Cu	Missouri	NE0.4	field	resident	omnivore	Insecta	.	.	.	.	12.20	263.2	.	Watson_et_al_1976
Cu	Missouri	NE0.8	field	resident	omnivore	Insecta	.	.	.	.	26.29	795.5	.	Watson_et_al_1976
Cu	Missouri	NE1.2	field	resident	omnivore	Insecta	.	.	.	.	35.08	768.4	.	Watson_et_al_1976
Cu	Missouri	NW0.4	field	resident	omnivore	Insecta	.	.	.	.	9.55	84.7	.	Watson_et_al_1976
Cu	Missouri	NW0.8	field	resident	omnivore	Insecta	.	.	.	.	3.19	32.8	.	Watson_et_al_1976
Cu	Missouri	NW1.2	field	resident	omnivore	Insecta	.	.	.	.	1.60	27.6	.	Watson_et_al_1976
Cu	Missouri	NW2.0	field	resident	omnivore	Insecta	.	.	.	.	1.00	31.8	.	Watson_et_al_1976
Cu	Missouri	W0.4	field	resident	omnivore	Insecta	.	.	.	.	6.79	156.6	.	Watson_et_al_1976
Cu	Missouri	W0.8	field	resident	omnivore	Insecta	.	.	.	.	1.93	47.3	.	Watson_et_al_1976
Cu	Missouri	W1.2	field	resident	omnivore	Insecta	.	.	.	.	1.17	43.5	.	Watson_et_al_1976
Cu	Missouri	W1.6	field	resident	omnivore	Insecta	.	.	.	.	0.96	28.8	.	Watson_et_al_1976
Cu	Missouri	W21.0_(reference)	field	resident	omnivore	Insecta	.	.	.	.	0.19	20.4	.	Watson_et_al_1976
Pb	Missouri	NE0.4	field	resident	omnivore	Insecta	.	.	.	.	55.12	2368.4	.	Watson_et_al_1976
Pb	Missouri	NE0.8	field	resident	omnivore	Insecta	.	.	.	.	22.39	3295.5	.	Watson_et_al_1976
Pb	Missouri	NE1.2	field	resident	omnivore	Insecta	.	.	.	.	30.57	2787.3	.	Watson_et_al_1976
Pb	Missouri	NW0.4	field	resident	omnivore	Insecta	.	.	.	.	60.52	3423.4	.	Watson_et_al_1976
Pb	Missouri	NW0.8	field	resident	omnivore	Insecta	.	.	.	.	20.39	214.8	.	Watson_et_al_1976
Pb	Missouri	NW1.2	field	resident	omnivore	Insecta	.	.	.	.	9.91	347.9	.	Watson_et_al_1976
Pb	Missouri	NW2.0	field	resident	omnivore	Insecta	.	.	.	.	5.33	326.9	.	Watson_et_al_1976
Pb	Missouri	W0.4	field	resident	omnivore	Insecta	.	.	.	.	51.22	2857.1	.	Watson_et_al_1976
Pb	Missouri	W0.8	field	resident	omnivore	Insecta	.	.	.	.	12.60	299.7	.	Watson_et_al_1976
Pb	Missouri	W1.2	field	resident	omnivore	Insecta	.	.	.	.	6.84	159.7	.	Watson_et_al_1976
Pb	Missouri	W1.6	field	resident	omnivore	Insecta	.	.	.	.	4.63	336.5	.	Watson_et_al_1976
Pb	Missouri	W21.0_(reference)	field	resident	omnivore	Insecta	.	.	.	.	0.32	102	.	Watson_et_al_1976
Zn	Missouri	NE0.4	field	resident	omnivore	Insecta	.	.	.	.	24.82	947.4	.	Watson_et_al_1976
Zn	Missouri	NE0.8	field	resident	omnivore	Insecta	.	.	.	.	15.03	590.9	.	Watson_et_al_1976
Zn	Missouri	NE1.2	field	resident	omnivore	Insecta	.	.	.	.	25.60	632.2	.	Watson_et_al_1976
Zn	Missouri	NW0.4	field	resident	omnivore	Insecta	.	.	.	.	18.30	405.4	.	Watson_et_al_1976
Zn	Missouri	NW0.8	field	resident	omnivore	Insecta	.	.	.	.	6.98	296.9	.	Watson_et_al_1976
Zn	Missouri	NW1.2	field	resident	omnivore	Insecta	.	.	.	.	4.56	244.2	.	Watson_et_al_1976
Zn	Missouri	NW2.0	field	resident	omnivore	Insecta	.	.	.	.	2.71	283	.	Watson_et_al_1976
Zn	Missouri	W0.4	field	resident	omnivore	Insecta	.	.	.	.	14.68	450.1	.	Watson_et_al_1976
Zn	Missouri	W0.8	field	resident	omnivore	Insecta	.	.	.	.	5.05	388	.	Watson_et_al_1976
Zn	Missouri	W1.2	field	resident	omnivore	Insecta	.	.	.	.	3.11	345.4	.	Watson_et_al_1976
Zn	Missouri	W1.6	field	resident	omnivore	Insecta	.	.	.	.	2.41	336.5	.	Watson_et_al_1976
Zn	Missouri	W21.0_(reference)	field	resident	omnivore	Insecta	.	.	.	.	0.84	232.1	.	Watson_et_al_1976
Cd	Missouri	NE0.4	field	resident	predator	Insecta	.	.	non-spider	.	128.82	12.5	.	Watson_et_al_1976
Cd	Missouri	NE0.8	field	resident	predator	Insecta	.	.	non-spider	.	49.86	11.7	.	Watson_et_al_1976
Cd	Missouri	NE1.2	field	resident	predator	Insecta	.	.	non-spider	.	62.06	11.2	.	Watson_et_al_1976
Cd	Missouri	NW0.4	field	resident	predator	Insecta	.	.	non-spider	.	124.54	33.7	.	Watson_et_al_1976
Cd	Missouri	NW0.8	field	resident	predator	Insecta	.	.	non-spider	.	42.97	8.1	.	Watson_et_al_1976
Cd	Missouri	NW1.2	field	resident	predator	Insecta	.	.	non-spider	.	29.80	19.4	.	Watson_et_al_1976
Cd	Missouri	NW2.0	field	resident	predator	Insecta	.	.	non-spider	.	15.36	11.1	.	Watson_et_al_1976
Cd	Missouri	W0.4	field	resident	predator	Insecta	.	.	non-spider	.	96.64	112.4	.	Watson_et_al_1976
Cd	Missouri	W0.8	field	resident	predator	Insecta	.	.	non-spider	.	34.94	28.9	.	Watson_et_al_1976
Cd	Missouri	W1.2	field	resident	predator	Insecta	.	.	non-spider	.	20.10	10.3	.	Watson_et_al_1976
Cd	Missouri	W1.6	field	resident	predator	Insecta	.	.	non-spider	.	15.85	12.4	.	Watson_et_al_1976
Cd	Missouri	W21.0_(reference)	field	resident	predator	Insecta	.	.	non-spider	.	0.11	4.7	.	Watson_et_al_1976
Cu	Missouri	NE0.4	field	resident	predator	Insecta	.	.	non-spider	.	12.20	136.2	.	Watson_et_al_1976
Cu	Missouri	NE0.8	field	resident	predator	Insecta	.	.	non-spider	.	26.29	83.3	.	Watson_et_al_1976
Cu	Missouri	NE1.2	field	resident	predator	Insecta	.	.	non-spider	.	35.08	169.1	.	Watson_et_al_1976
Cu	Missouri	NW0.4	field	resident	predator	Insecta	.	.	non-spider	.	9.55	320.5	.	Watson_et_al_1976
Cu	Missouri	NW0.8	field	resident	predator	Insecta	.	.	non-spider	.	3.19	37.5	.	Watson_et_al_1976
Cu	Missouri	NW1.2	field	resident	predator	Insecta	.	.	non-spider	.	1.60	98	.	Watson_et_al_1976

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	Species	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Cu	Missouri	NW2.0	field	resident	predator	Insecta	.	.	non-spider	.	1.00	59.4	.	Watson_et_al_1976
Cu	Missouri	W0.4	field	resident	predator	Insecta	.	.	non-spider	.	6.79	547.8	.	Watson_et_al_1976
Cu	Missouri	W0.8	field	resident	predator	Insecta	.	.	non-spider	.	1.93	138.9	.	Watson_et_al_1976
Cu	Missouri	W1.2	field	resident	predator	Insecta	.	.	non-spider	.	1.17	32.5	.	Watson_et_al_1976
Cu	Missouri	W1.6	field	resident	predator	Insecta	.	.	non-spider	.	0.96	28.1	.	Watson_et_al_1976
Cu	Missouri	W21.0_(reference)	field	resident	predator	Insecta	.	.	non-spider	.	0.19	48.6	.	Watson_et_al_1976
Pb	Missouri	NE0.4	field	resident	predator	Insecta	.	.	non-spider	.	55.12	2316.1	.	Watson_et_al_1976
Pb	Missouri	NE0.8	field	resident	predator	Insecta	.	.	non-spider	.	22.39	533.3	.	Watson_et_al_1976
Pb	Missouri	NE1.2	field	resident	predator	Insecta	.	.	non-spider	.	30.57	1964.6	.	Watson_et_al_1976
Pb	Missouri	NW0.4	field	resident	predator	Insecta	.	.	non-spider	.	60.52	15000	.	Watson_et_al_1976
Pb	Missouri	NW0.8	field	resident	predator	Insecta	.	.	non-spider	.	20.39	150.1	.	Watson_et_al_1976
Pb	Missouri	NW1.2	field	resident	predator	Insecta	.	.	non-spider	.	9.91	283.2	.	Watson_et_al_1976
Pb	Missouri	NW2.0	field	resident	predator	Insecta	.	.	non-spider	.	5.33	162	.	Watson_et_al_1976
Pb	Missouri	W0.4	field	resident	predator	Insecta	.	.	non-spider	.	51.22	28370.8	.	Watson_et_al_1976
Pb	Missouri	W0.8	field	resident	predator	Insecta	.	.	non-spider	.	12.60	2430.6	.	Watson_et_al_1976
Pb	Missouri	W1.2	field	resident	predator	Insecta	.	.	non-spider	.	6.84	528.9	.	Watson_et_al_1976
Pb	Missouri	W1.6	field	resident	predator	Insecta	.	.	non-spider	.	4.63	118.2	.	Watson_et_al_1976
Pb	Missouri	W21.0_(reference)	field	resident	predator	Insecta	.	.	non-spider	.	0.32	27.9	.	Watson_et_al_1976
Zn	Missouri	NE0.4	field	resident	predator	Insecta	.	.	non-spider	.	24.82	340.6	.	Watson_et_al_1976
Zn	Missouri	NE0.8	field	resident	predator	Insecta	.	.	non-spider	.	15.03	406.7	.	Watson_et_al_1976
Zn	Missouri	NE1.2	field	resident	predator	Insecta	.	.	non-spider	.	25.60	542.1	.	Watson_et_al_1976
Zn	Missouri	NW0.4	field	resident	predator	Insecta	.	.	non-spider	.	18.30	359	.	Watson_et_al_1976
Zn	Missouri	NW0.8	field	resident	predator	Insecta	.	.	non-spider	.	6.98	281.4	.	Watson_et_al_1976
Zn	Missouri	NW1.2	field	resident	predator	Insecta	.	.	non-spider	.	4.56	727.7	.	Watson_et_al_1976
Zn	Missouri	NW2.0	field	resident	predator	Insecta	.	.	non-spider	.	2.71	459	.	Watson_et_al_1976
Zn	Missouri	W0.4	field	resident	predator	Insecta	.	.	non-spider	.	14.68	848.3	.	Watson_et_al_1976
Zn	Missouri	W0.8	field	resident	predator	Insecta	.	.	non-spider	.	5.05	726.9	.	Watson_et_al_1976
Zn	Missouri	W1.2	field	resident	predator	Insecta	.	.	non-spider	.	3.11	433.7	.	Watson_et_al_1976
Zn	Missouri	W1.6	field	resident	predator	Insecta	.	.	non-spider	.	2.41	365.9	.	Watson_et_al_1976
Zn	Missouri	W21.0_(reference)	field	resident	predator	Insecta	.	.	non-spider	.	0.84	556.5	.	Watson_et_al_1976
Cd	Missouri	NE0.4	field	resident	predator	Arachinida	Araneae	.	spider	.	128.82	34.6	.	Watson_et_al_1976
Cd	Missouri	NE0.8	field	resident	predator	Arachinida	Araneae	.	spider	.	49.86	53.4	.	Watson_et_al_1976
Cd	Missouri	NE1.2	field	resident	predator	Arachinida	Araneae	.	spider	.	62.06	75.9	.	Watson_et_al_1976
Cd	Missouri	NW0.4	field	resident	predator	Arachinida	Araneae	.	spider	.	124.54	100	.	Watson_et_al_1976
Cd	Missouri	NW0.8	field	resident	predator	Arachinida	Araneae	.	spider	.	42.97	41.3	.	Watson_et_al_1976
Cd	Missouri	NW1.2	field	resident	predator	Arachinida	Araneae	.	spider	.	29.80	9.7	.	Watson_et_al_1976
Cd	Missouri	NW2.0	field	resident	predator	Arachinida	Araneae	.	spider	.	15.36	36.1	.	Watson_et_al_1976
Cd	Missouri	W0.4	field	resident	predator	Arachinida	Araneae	.	spider	.	96.64	76.5	.	Watson_et_al_1976
Cd	Missouri	W0.8	field	resident	predator	Arachinida	Araneae	.	spider	.	34.94	95.1	.	Watson_et_al_1976
Cd	Missouri	W1.2	field	resident	predator	Arachinida	Araneae	.	spider	.	20.10	53.8	.	Watson_et_al_1976
Cd	Missouri	W1.6	field	resident	predator	Arachinida	Araneae	.	spider	.	15.85	41.9	.	Watson_et_al_1976
Cd	Missouri	W21.0_(reference)	field	resident	predator	Arachinida	Araneae	.	spider	.	0.11	4.1	.	Watson_et_al_1976
Cu	Missouri	NE0.4	field	resident	predator	Arachinida	Araneae	.	spider	.	12.20	448.7	.	Watson_et_al_1976
Cu	Missouri	NE0.8	field	resident	predator	Arachinida	Araneae	.	spider	.	26.29	626	.	Watson_et_al_1976
Cu	Missouri	NE1.2	field	resident	predator	Arachinida	Araneae	.	spider	.	35.08	480	.	Watson_et_al_1976
Cu	Missouri	NW0.4	field	resident	predator	Arachinida	Araneae	.	spider	.	9.55	242.9	.	Watson_et_al_1976
Cu	Missouri	NW0.8	field	resident	predator	Arachinida	Araneae	.	spider	.	3.19	181.5	.	Watson_et_al_1976
Cu	Missouri	NW1.2	field	resident	predator	Arachinida	Araneae	.	spider	.	1.60	72.9	.	Watson_et_al_1976
Cu	Missouri	NW2.0	field	resident	predator	Arachinida	Araneae	.	spider	.	1.00	151.9	.	Watson_et_al_1976
Cu	Missouri	W0.4	field	resident	predator	Arachinida	Araneae	.	spider	.	6.79	197.4	.	Watson_et_al_1976
Cu	Missouri	W0.8	field	resident	predator	Arachinida	Araneae	.	spider	.	1.93	176.6	.	Watson_et_al_1976
Cu	Missouri	W1.2	field	resident	predator	Arachinida	Araneae	.	spider	.	1.17	174.1	.	Watson_et_al_1976
Cu	Missouri	W1.6	field	resident	predator	Arachinida	Araneae	.	spider	.	0.96	129.8	.	Watson_et_al_1976
Cu	Missouri	W21.0_(reference)	field	resident	predator	Arachinida	Araneae	.	spider	.	0.19	72.9	.	Watson_et_al_1976

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	*Species*	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Pb	Missouri	NE0.4	field	resident	predator	Arachinida	Araneae	.	spider	.	55.12	6089.7	.	Watson_et_al_1976
Pb	Missouri	NE0.8	field	resident	predator	Arachinida	Araneae	.	spider	.	22.39	1389.3	.	Watson_et_al_1976
Pb	Missouri	NE1.2	field	resident	predator	Arachinida	Araneae	.	spider	.	30.57	209.4	.	Watson_et_al_1976
Pb	Missouri	NW0.4	field	resident	predator	Arachinida	Araneae	.	spider	.	60.52	3514.3	.	Watson_et_al_1976
Pb	Missouri	NW0.8	field	resident	predator	Arachinida	Araneae	.	spider	.	20.39	267.3	.	Watson_et_al_1976
Pb	Missouri	NW1.2	field	resident	predator	Arachinida	Araneae	.	spider	.	9.91	288.4	.	Watson_et_al_1976
Pb	Missouri	NW2.0	field	resident	predator	Arachinida	Araneae	.	spider	.	5.33	112.5	.	Watson_et_al_1976
Pb	Missouri	W0.4	field	resident	predator	Arachinida	Araneae	.	spider	.	51.22	1659.5	.	Watson_et_al_1976
Pb	Missouri	W0.8	field	resident	predator	Arachinida	Araneae	.	spider	.	12.60	326.1	.	Watson_et_al_1976
Pb	Missouri	W1.2	field	resident	predator	Arachinida	Araneae	.	spider	.	6.84	195	.	Watson_et_al_1976
Pb	Missouri	W1.6	field	resident	predator	Arachinida	Araneae	.	spider	.	4.63	536.9	.	Watson_et_al_1976
Pb	Missouri	W21.0_(reference)	field	resident	predator	Arachinida	Araneae	.	spider	.	0.32	18.2	.	Watson_et_al_1976
Zn	Missouri	NE0.4	field	resident	predator	Arachinida	Araneae	.	spider	.	24.82	935.9	.	Watson_et_al_1976
Zn	Missouri	NE0.8	field	resident	predator	Arachinida	Araneae	.	spider	.	15.03	729.8	.	Watson_et_al_1976
Zn	Missouri	NE1.2	field	resident	predator	Arachinida	Araneae	.	spider	.	25.60	1165.7	.	Watson_et_al_1976
Zn	Missouri	NW0.4	field	resident	predator	Arachinida	Araneae	.	spider	.	18.30	822.9	.	Watson_et_al_1976
Zn	Missouri	NW0.8	field	resident	predator	Arachinida	Araneae	.	spider	.	6.98	709.6	.	Watson_et_al_1976
Zn	Missouri	NW1.2	field	resident	predator	Arachinida	Araneae	.	spider	.	4.56	485.7	.	Watson_et_al_1976
Zn	Missouri	NW2.0	field	resident	predator	Arachinida	Araneae	.	spider	.	2.71	465.7	.	Watson_et_al_1976
Zn	Missouri	W0.4	field	resident	predator	Arachinida	Araneae	.	spider	.	14.68	647.8	.	Watson_et_al_1976
Zn	Missouri	W0.8	field	resident	predator	Arachinida	Araneae	.	spider	.	5.05	872.4	.	Watson_et_al_1976
Zn	Missouri	W1.2	field	resident	predator	Arachinida	Araneae	.	spider	.	3.11	527.9	.	Watson_et_al_1976
Zn	Missouri	W1.6	field	resident	predator	Arachinida	Araneae	.	spider	.	2.41	536.9	.	Watson_et_al_1976
Zn	Missouri	W21.0_(reference)	field	resident	predator	Arachinida	Araneae	.	spider	.	0.84	532.5	.	Watson_et_al_1976
Cu	Austria	1	field	resident	detritivore	Isopoda	.	.	*isopods*	.	72.00	115	.	Wieser_et_al_1976
Cu	Austria	2	field	resident	detritivore	Isopoda	.	.	*isopods*	.	13.00	187	.	Wieser_et_al_1976
Cu	Austria	3	field	resident	detritivore	Isopoda	.	.	*isopods*	.	85.00	74	.	Wieser_et_al_1976
Cu	Austria	5	field	resident	detritivore	Isopoda	.	.	*isopods*	.	570.00	538	.	Wieser_et_al_1976
Cu	Austria	4a	field	resident	detritivore	Isopoda	.	.	*isopods*	.	540.00	487	.	Wieser_et_al_1976
Cu	Austria	4b	field	resident	detritivore	Isopoda	.	.	*isopods*	.	1002.00	460	.	Wieser_et_al_1976
Cu	Austria	4c	field	resident	detritivore	Isopoda	.	.	*isopods*	.	61.00	184	.	Wieser_et_al_1976
Cu	Austria	6	field	resident	detritivore	Isopoda	.	.	*P._scaber,_P.picuts*	25.00	41.00	170	.	Wieser_et_al_1977
Cu	Austria	7	field	resident	detritivore	Isopoda	.	.	*Tracheoniscus_rathkei*	16.00	22.00	174	.	Wieser_et_al_1977
Cu	Austria	8	field	resident	detritivore	Isopoda	.	.	*acheoniscus_rathkei,_P.pict*	42.00	20.00	258	.	Wieser_et_al_1977
Cu	Austria	9	field	resident	detritivore	Isopoda	.	.	*acheoniscus_rathkei,_P.pict*	.	22.00	180	.	Wieser_et_al_1977
Cu	Austria	10	field	resident	detritivore	Isopoda	.	.	*Pictus,_P._Scabe,_T._Rath*	45.00	21.00	272	.	Wieser_et_al_1977
Cu	Austria	11	field	resident	detritivore	Isopoda	.	.	*Pictus,_P._Scabe,_T._Rath*	19.00	16.00	132	.	Wieser_et_al_1977
Cu	Austria	12	field	resident	detritivore	Isopoda	.	.	*O._Asellus,_P._Scaber*	31.00	47.00	205	.	Wieser_et_al_1977
Cd	Lab	6a	lab	6months	detritivore	Isopoda	.	.	*Porcellio_Scaber*	.	.	3.20	.	Witzel_1998
Cd	Lab	6a	lab	6months	detritivore	Isopoda	.	.	*Porcellio_Scaber*	.	.	42.90	.	Witzel_1998
Cd	Lab	6a	lab	6months	detritivore	Isopoda	.	.	*Porcellio_Scaber*	.	.	511.40	.	Witzel_1998
Cd	Lab	6b	lab	6months	detritivore	Isopoda	.	.	*Porcellio_Scaber*	.	.	3.27	.	Witzel_1998
Cd	Lab	6b	lab	6months	detritivore	Isopoda	.	.	*Porcellio_Scaber*	.	.	46.90	.	Witzel_1998
Pb	Lab	6a	lab	6months	detritivore	Isopoda	.	.	*Porcellio_Scaber*	.	.	2.00	.	Witzel_1998
Pb	Lab	6a	lab	6months	detritivore	Isopoda	.	.	*Porcellio_Scaber*	.	.	10.80	.	Witzel_1998
Pb	Lab	6a	lab	6months	detritivore	Isopoda	.	.	*Porcellio_Scaber*	.	.	151.7	.	Witzel_1998
Pb	Lab	6b	lab	6months	detritivore	Isopoda	.	.	*Porcellio_Scaber*	.	.	1.90	.	Witzel_1998
Pb	Lab	6b	lab	6months	detritivore	Isopoda	.	.	*Porcellio_Scaber*	.	.	14.20	.	Witzel_1998
As	Montana	WSCT1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	1400	97.6	J	PTI_1994
As	Montana	WSCRFT1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	65.4	6.2	J	PTI_1994
As	Montana	WSCR1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	477.9	53.7	J	PTI_1994
As	Montana	WSCRFR1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	35.3	3.9	J	PTI_1994
As	Montana	SBCT1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	178	22.4	.	PTI_1994
As	Montana	SBCT1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	178	6.6	.	PTI_1994

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	*Species*	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
As	Montana	SBCR1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	193	15.6	.	PTI_1994
As	Montana	WSCR1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	477.9	65.4	.	PTI_1994
As	Montana	WSCR1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	477.9	75.9	.	PTI_1994
Cd	Montana	WSCT1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	4.6	2.6	.	PTI_1994
Cd	Montana	WSCRFT1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	1.7	0.76	.	PTI_1994
Cd	Montana	WSCR1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	7.3	1.1	.	PTI_1994
Cd	Montana	WSCRFR1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	0.3	0.76	.	PTI_1994
Cd	Montana	SBCT1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	2.2	0.72	.	PTI_1994
Cd	Montana	SBCT1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	2.2	6.7	.	PTI_1994
Cd	Montana	SBCR1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	2.6	3.1	.	PTI_1994
Cd	Montana	WSCR1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	7.3	0.78	.	PTI_1994
Cd	Montana	WSCR1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	7.3	4.4	.	PTI_1994
Cu	Montana	WSCT1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	1200	212	.	PTI_1994
Cu	Montana	WSCRFT1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	127	42.1	.	PTI_1994
Cu	Montana	WSCR1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	1701	99.5	.	PTI_1994
Cu	Montana	WSCRFR1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	31.4	23.4	.	PTI_1994
Cu	Montana	SBCT1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	193	27.2	.	PTI_1994
Cu	Montana	SBCT1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	193	71.5	.	PTI_1994
Cu	Montana	SBCR1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	391	111	.	PTI_1994
Cu	Montana	WSCR1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	1701	91.2	.	PTI_1994
Cu	Montana	WSCR1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	1701	87.9	.	PTI_1994
Pb	Montana	WSCT1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	491	43	.	PTI_1994
Pb	Montana	WSCRFT1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	40.1	3.2	.	PTI_1994
Pb	Montana	WSCR1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	191.7	6.2	.	PTI_1994
Pb	Montana	WSCRFR1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	8.6	1.9	.	PTI_1994
Pb	Montana	SBCT1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	68	3.9	J	PTI_1994
Pb	Montana	SBCT1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	68	1.7	J	PTI_1994
Pb	Montana	SBCR1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	303	22.7	J	PTI_1994
Pb	Montana	WSCR1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	191.7	5	J	PTI_1994
Pb	Montana	WSCR1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	191.7	5.3	J	PTI_1994
Zn	Montana	WSCT1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	817	303	.	PTI_1994
Zn	Montana	WSCRFT1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	149	150	.	PTI_1994
Zn	Montana	WSCR1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	756.7	184	.	PTI_1994
Zn	Montana	WSCRFR1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	57.1	127	.	PTI_1994
Zn	Montana	SBCT1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	148	120	.	PTI_1994
Zn	Montana	SBCT1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	148	215	.	PTI_1994
Zn	Montana	SBCR1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	911	322	.	PTI_1994
Zn	Montana	WSCR1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	756.7	200	.	PTI_1994
Zn	Montana	WSCR1	field	resident	.	Insecta	Coleoptera	.	BEETLE	.	756.7	217	.	PTI_1994
As	Montana	WSCT1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	1400	20.8	J	PTI_1994
As	Montana	WSCRFT1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	65.4	2.3	J	PTI_1994
As	Montana	WSCR1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	477.9	28.5	J	PTI_1994
As	Montana	WSCRFR1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	35.3	1.4	J	PTI_1994
As	Montana	SBCR1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	193	3.4	.	PTI_1994
As	Montana	SBCT1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	178	10	.	PTI_1994
As	Montana	WSCR1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	477.9	34.5	.	PTI_1994
As	Montana	WSCR1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	477.9	32.7	.	PTI_1994
Cd	Montana	WSCT1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	4.6	2.5	.	PTI_1994
Cd	Montana	WSCRFT1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	1.7	0.37	.	PTI_1994
Cd	Montana	WSCR1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	7.3	0.88	.	PTI_1994
Cd	Montana	WSCRFR1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	0.3	0.49	.	PTI_1994
Cd	Montana	SBCR1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	2.6	1.9	.	PTI_1994
Cd	Montana	SBCT1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	2.2	1.1	.	PTI_1994
Cd	Montana	WSCR1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	7.3	1.4	.	PTI_1994

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	Species	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Cd	Montana	WSCR1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	7.3	1.4	.	PTI_1994
Cu	Montana	WSCT1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	1200	286	.	PTI_1994
Cu	Montana	WSCRFT1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	127	80	.	PTI_1994
Cu	Montana	WSCR1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	1701	178	.	PTI_1994
Cu	Montana	WSCRFR1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	31.4	83.6	.	PTI_1994
Cu	Montana	SBCR1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	391	189	.	PTI_1994
Cu	Montana	SBCT1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	193	117	.	PTI_1994
Cu	Montana	WSCR1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	1701	202	.	PTI_1994
Cu	Montana	WSCR1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	1701	170	.	PTI_1994
Pb	Montana	WSCT1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	491	8.3	.	PTI_1994
Pb	Montana	WSCRFT1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	40.1	1.3	.	PTI_1994
Pb	Montana	WSCR1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	191.7	12.6	.	PTI_1994
Pb	Montana	WSCRFR1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	8.6	1.3	.	PTI_1994
Pb	Montana	SBCR1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	303	4.2	J	PTI_1994
Pb	Montana	SBCT1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	68	3.8	J	PTI_1994
Pb	Montana	WSCR1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	191.7	12.3	J	PTI_1994
Pb	Montana	WSCR1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	191.7	11.9	J	PTI_1994
Zn	Montana	WSCT1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	817	279	.	PTI_1994
Zn	Montana	WSCRFT1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	149	176	.	PTI_1994
Zn	Montana	WSCR1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	756.7	277	.	PTI_1994
Zn	Montana	WSCRFR1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	57.1	201	.	PTI_1994
Zn	Montana	SBCR1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	911	282	.	PTI_1994
Zn	Montana	SBCT1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	148	166	.	PTI_1994
Zn	Montana	WSCR1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	756.7	276	.	PTI_1994
Zn	Montana	WSCR1	field	resident	.	Insecta	Orthoptera	Acrididae	GRASSHOPPER	.	756.7	257	.	PTI_1994
As	Montana	WSCT1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	1400	99.3	J	PTI_1994
As	Montana	WSCRFT1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	65.4	11.3	J	PTI_1994
As	Montana	WSCR1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	477.9	32	J	PTI_1994
As	Montana	WSCRFR1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	35.3	12.5	J	PTI_1994
As	Montana	SBCR1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	193	33.7	.	PTI_1994
As	Montana	SBCT1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	178	49.5	.	PTI_1994
As	Montana	WSCR1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	477.9	50.9	.	PTI_1994
As	Montana	WSCR1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	477.9	59.1	.	PTI_1994
Cd	Montana	WSCT1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	4.6	19.1	.	PTI_1994
Cd	Montana	WSCRFT1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	1.7	4.8	.	PTI_1994
Cd	Montana	WSCR1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	7.3	2.9	.	PTI_1994
Cd	Montana	WSCRFR1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	0.3	5.9	.	PTI_1994
Cd	Montana	SBCR1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	2.6	13.5	.	PTI_1994
Cd	Montana	SBCT1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	2.2	8.3	.	PTI_1994
Cd	Montana	WSCR1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	7.3	3.5	.	PTI_1994
Cd	Montana	WSCR1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	7.3	4	.	PTI_1994
Cu	Montana	WSCT1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	1200	386	.	PTI_1994
Cu	Montana	WSCRFT1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	127	42.7	.	PTI_1994
Cu	Montana	WSCR1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	1701	179	.	PTI_1994
Cu	Montana	WSCRFR1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	31.4	63.6	.	PTI_1994
Cu	Montana	SBCR1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	391	318	.	PTI_1994
Cu	Montana	SBCT1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	193	93.9	.	PTI_1994
Cu	Montana	WSCR1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	1701	214	.	PTI_1994
Cu	Montana	WSCR1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	1701	298	.	PTI_1994
Pb	Montana	WSCT1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	491	43	.	PTI_1994
Pb	Montana	WSCRFT1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	40.1	5.7	.	PTI_1994
Pb	Montana	WSCR1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	191.7	16.2	.	PTI_1994
Pb	Montana	WSCRFR1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	8.6	8.7	.	PTI_1994
Pb	Montana	SBCR1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	303	50.8	J	PTI_1994

Appendix B-1. Literature-derived data for calculation of soil-terrestrial invertebrate contaminant uptake factors.

Analyte	Study_Location	Sample_Location	Lab/Field	Duration	Trophic Level	Class	Order	Family	*Species*	Plant Conc mg/kg dry wt	Soil Conc mg/kg dry wt	Arthropod Conc mg/kg dry wt	Qualifier	Reference
Pb	Montana	SBCT1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	68	16.2	J	PTI_1994
Pb	Montana	WSCR1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	191.7	22.2	J	PTI_1994
Pb	Montana	WSCR1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	191.7	28.9	J	PTI_1994
Zn	Montana	WSCT1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	817	519	.	PTI_1994
Zn	Montana	WSCRFT1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	149	350	.	PTI_1994
Zn	Montana	WSCR1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	756.7	425	.	PTI_1994
Zn	Montana	WSCRFR1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	57.1	416	.	PTI_1994
Zn	Montana	SBCR1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	911	855	.	PTI_1994
Zn	Montana	SBCT1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	148	350	.	PTI_1994
Zn	Montana	WSCR1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	756.7	504	.	PTI_1994
Zn	Montana	WSCR1	field	resident	.	Arachnida	Araneae	.	SPIDER	.	756.7	802	.	PTI_1994

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
2-ADNT	lab	0	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	leaf	1	.	.	PalazzoandLeggett1986
2-ADNT	lab	5	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	leaf	38	.	.	PalazzoandLeggett1986
2-ADNT	lab	10	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	leaf	65	.	.	PalazzoandLeggett1986
2-ADNT	lab	20	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	leaf	105	.	.	PalazzoandLeggett1986
2-ADNT	lab	0	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	1	.	.	PalazzoandLeggett1986
2-ADNT	lab	5	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	73	.	.	PalazzoandLeggett1986
2-ADNT	lab	10	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	93	.	.	PalazzoandLeggett1986
2-ADNT	lab	20	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	171	.	.	PalazzoandLeggett1986
2-ADNT	lab	0	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	7	.	.	PalazzoandLeggett1986
2-ADNT	lab	5	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	450	.	.	PalazzoandLeggett1986
2-ADNT	lab	10	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	601	.	.	PalazzoandLeggett1986
2-ADNT	lab	20	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	614	.	.	PalazzoandLeggett1986
2-ADNT	lab	0	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	0	.	.	PalazzoandLeggett1986
2-ADNT	lab	5	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	26	.	.	PalazzoandLeggett1986
2-ADNT	lab	10	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	104	.	.	PalazzoandLeggett1986
2-ADNT	lab	20	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	77	.	.	PalazzoandLeggett1986
2-ADNT	Iowa	8	field	resident	arrowhead	Dicot	*Saggitariacalycina*	.	.	.	0.5	U	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	20	field	resident	blacklocust	Dicot	Robiniapseudo-acacia	.	.	.	11	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	111	field	resident	blacklocust	Dicot	*Robiniapseudo-acacia*	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	144-2	field	resident	blacklocust	Dicot	*Robiniapseudo-acacia*	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	112-1	field	resident	milkweed	Dicot	*Asclepiassyriaca*	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	9	field	resident	Corn	Monocot	*Zeamays*	.	.	.	0.5	U	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	10	field	resident	Corn	Monocot	*Zeamays*	.	.	.	0.5	U	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	11	field	resident	Corn	Monocot	*Zeamays*	.	.	.	0.5	U	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	101	field	resident	Corn	Monocot	*Zeamays*	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	102	field	resident	Corn	Monocot	*Zeamays*	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	103	field	resident	Corn	Monocot	*Zeamays*	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	14	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	0.5	U	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	18	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	2.8	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	109	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	112-2	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	114-1	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	19-2	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	0.5	U	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	5	field	resident	Pigweed	Dicot	*Amaranthussp.*	.	.	.	0.5	U	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	106	field	resident	Pigweed	Dicot	*Amaranthussp.*	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	21	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	.	.	.	0.5	U	leaf/stem	4.5	.	.	Schneider_et_al_1995
2-ADNT	Iowa	107	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	108	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	113	field	resident	redcedar	Gymnosperm	*Juniperusviginiana*	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	12	field	resident	reedcanarygrass	Monocot	Phalarisarundinacea	.	.	.	1.5	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	17	field	resident	reedcanarygrass	Monocot	Phalarisarundinacea	.	.	.	0.5	U	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	110	field	resident	reedcanarygrass	Monocot	*Phalarisarundinacea*	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	19-1	field	resident	reedcanarygrass	Monocot	Phalarisarundinacea	.	.	.	0.5	U	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	1	field	resident	smartweed	Dicot	*Polygonumsp.*	.	.	.	0.5	U	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	104	field	resident	smartweed	Dicot	*Polygonumsp.*	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	4	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	0.5	U	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	105	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	112-3	field	resident	sunflower	Dicot	*Helianthusnutallii*	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	8	field	resident	arrowhead	Dicot	*Saggitariacalycina*	.	.	.	0.5	U	root	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	20	field	resident	blacklocust	Dicot	Robiniapseudo-acacia	.	.	.	11	.	root	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	112-1	field	resident	milkweed	Dicot	*Asclepiassyriaca*	.	.	.	.	.	root	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	101	field	resident	Corn	Monocot	*Zeamays*	.	.	.	.	.	root	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	102	field	resident	Corn	Monocot	*Zeamays*	.	.	.	.	.	root	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	103	field	resident	Corn	Monocot	*Zeamays*	.	.	.	.	.	root	0.5	U	.	Schneider_et_al_1995

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
2-ADNT	Iowa	14	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	0.5	U	root	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	18	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	2.8	.	root	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	109	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	.	.	root	4.4	.	.	Schneider_et_al_1995
2-ADNT	Iowa	112-2	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	.	.	root	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	19-2	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	0.5	U	root	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	5	field	resident	Pigweed	Dicot	*Amaranthussp.*	.	.	.	0.5	U	root	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	106	field	resident	Pigweed	Dicot	*Amaranthussp.*	.	.	.	.	.	root	12	.	.	Schneider_et_al_1995
2-ADNT	Iowa	21	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	.	.	.	0.5	U	root	19.8	.	.	Schneider_et_al_1995
2-ADNT	Iowa	107	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	.	.	.	.	.	root	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	108	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	.	.	.	.	.	root	14.8	.	.	Schneider_et_al_1995
2-ADNT	Iowa	17	field	resident	reedcanarygrass	Monocot	Phalarisarundinacea	.	.	.	0.5	U	root	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	110	field	resident	reedcanarygrass	Monocot	*Phalarisarundinacea*	.	.	.	.	.	root	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	19-1	field	resident	reedcanarygrass	Monocot	Phalarisarundinacea	.	.	.	0.5	U	root	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	1	field	resident	smartweed	Dicot	*Polygonumsp.*	.	.	.	0.5	U	root	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	104	field	resident	smartweed	Dicot	*Polygonumsp.*	.	.	.	.	.	root	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	4	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	0.5	U	root	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	105	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	.	.	root	9.3	.	.	Schneider_et_al_1995
2-ADNT	Iowa	112-3	field	resident	sunflower	Dicot	*Helianthusnutallii*	.	.	.	.	.	root	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	101	field	resident	Corn	Monocot	*Zeamays*	.	.	.	.	.	seed	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	102	field	resident	Corn	Monocot	*Zeamays*	.	.	.	.	.	seed	0.5	U	.	Schneider_et_al_1995
2-ADNT	Iowa	103	field	resident	Corn	Monocot	*Zeamays*	.	.	.	.	.	seed	0.5	U	.	Schneider_et_al_1995
2-ADNT	Illinois	13	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	5340	.	root	0.2	U	.	Zellmer_et_al_1995
2-ADNT	Illinois	14	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	3350	.	root	0.2	U	.	Zellmer_et_al_1995
2-ADNT	Illinois	4	field	resident	bluevervain	Monocot	*Verbenahastata*	.	.	.	1.5	.	root	0.2	U	.	Zellmer_et_al_1995
2-ADNT	Illinois	10	field	resident	chicory	Dicot	*Cichoriumintybus*	.	.	.	3360	.	root	0.2	U	.	Zellmer_et_al_1995
2-ADNT	Illinois	14	field	resident	chicory	Dicot	*Cichoriumintybus*	.	.	.	3350	.	root	0.2	U	.	Zellmer_et_al_1995
2-ADNT	Illinois	15	field	resident	chicory	Dicot	*Cichoriumintybus*	.	.	.	202	.	root	0.2	U	.	Zellmer_et_al_1995
2-ADNT	Illinois	5	field	resident	groundcherry	Monocot	*Physalisheterophylla*	.	.	.	1.6	.	root	0.2	U	.	Zellmer_et_al_1995
2-ADNT	Illinois	1	field	resident	milkweed	Dicot	*Asciepiassyriaca*	.	.	.	0.08	U	root	0.2	U	.	Zellmer_et_al_1995
2-ADNT	Illinois	3	field	resident	milkweed	Dicot	*Asciepiassyriaca*	.	.	.	1	.	root	0.2	U	.	Zellmer_et_al_1995
2-ADNT	Illinois	8	field	resident	milkweed	Dicot	*Asciepiassyriaca*	.	.	.	278	.	root	0.2	U	.	Zellmer_et_al_1995
2-ADNT	Illinois	14	field	resident	milkweed	Dicot	*Asciepiassyriaca*	.	.	.	3350	.	root	0.2	U	.	Zellmer_et_al_1995
2-ADNT	Illinois	2	field	resident	commonteasel	Dicot	*Dipsacussylvestris*	.	.	.	0.08	U	root	0.2	U	.	Zellmer_et_al_1995
2-ADNT	Illinois	6	field	resident	commonteasel	Dicot	*Dipsacussylvestris*	.	.	.	6260	.	root	1.15	.	.	Zellmer_et_al_1995
2-ADNT	Illinois	7	field	resident	commonteasel	Dicot	*Dipsacussylvestris*	.	.	.	492	.	root	0.2	U	.	Zellmer_et_al_1995
2-ADNT	Illinois	12	field	resident	commonteasel	Dicot	*Dipsacussylvestris*	.	.	.	39350	.	root	0.2	U	.	Zellmer_et_al_1995
2-ADNT	Illinois	3	field	resident	falseboneset	Dicot	*Kuhniaeupatorioides*	.	.	.	0.08	U	root	0.93	.	.	Zellmer_et_al_1995
2-ADNT	Illinois	10	field	resident	QueenAnne'slace	Dicot	*Daucuscarota*	.	.	.	3360	.	root	0.2	U	.	Zellmer_et_al_1995
2-ADNT	Illinois	15	field	resident	QueenAnne'slace	Dicot	*Daucuscarota*	.	.	.	202	.	root	0.2	U	.	Zellmer_et_al_1995
2-ADNT	Illinois	1	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	0.08	U	root	0.2	U	.	Zellmer_et_al_1995
2-ADNT	Illinois	2	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	0.08	U	root	0.2	U	.	Zellmer_et_al_1995
2-ADNT	Illinois	3	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	1	.	root	0.2	U	.	Zellmer_et_al_1995
2-ADNT	Illinois	4	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	1.5	.	root	0.2	U	.	Zellmer_et_al_1995
2-ADNT	Illinois	5	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	1.6	.	root	0.2	U	.	Zellmer_et_al_1995
2-ADNT	Illinois	6	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	6260	.	root	4.43	.	.	Zellmer_et_al_1995
2-ADNT	Illinois	7	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	492	.	root	0.2	U	.	Zellmer_et_al_1995
2-ADNT	Illinois	8	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	278	.	root	1.28	.	.	Zellmer_et_al_1995
2-ADNT	Illinois	9	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	5840	.	root	7.71	.	.	Zellmer_et_al_1995
2-ADNT	Illinois	11	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	3410	.	root	0.2	U	.	Zellmer_et_al_1995
2-ADNT	Illinois	12	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	39350	.	root	4.35	.	.	Zellmer_et_al_1995
2-ADNT	Illinois	13	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	5340	.	root	3.2	.	.	Zellmer_et_al_1995
2-ADNT	Illinois	14	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	3350	.	root	1.13	.	.	Zellmer_et_al_1995
4-ADNT	lab	0	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	leaf	1	.	.	PalazzoandLeggett1986
4-ADNT	lab	5	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	leaf	43	.	.	PalazzoandLeggett1986

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
4-ADNT	lab	10	lab	42days	yellow nutsedge	Monocot	Cyperusesculentus	.	.	.	.	.	leaf	58	.	.	PalazzoandLeggett1986
4-ADNT	lab	20	lab	42days	yellow nutsedge	Monocot	Cyperusesculentus	.	.	.	.	.	leaf	125	.	.	PalazzoandLeggett1986
4-ADNT	lab	0	lab	42days	yellow nutsedge	Monocot	Cyperusesculentus	.	.	.	.	.	root	5	.	.	PalazzoandLeggett1986
4-ADNT	lab	5	lab	42days	yellow nutsedge	Monocot	Cyperusesculentus	.	.	.	.	.	root	181	.	.	PalazzoandLeggett1986
4-ADNT	lab	10	lab	42days	yellow nutsedge	Monocot	Cyperusesculentus	.	.	.	.	.	root	288	.	.	PalazzoandLeggett1986
4-ADNT	lab	20	lab	42days	yellow nutsedge	Monocot	Cyperusesculentus	.	.	.	.	.	root	529	.	.	PalazzoandLeggett1986
4-ADNT	lab	0	lab	42days	yellow nutsedge	Monocot	Cyperusesculentus	.	.	.	.	.	root	18	.	.	PalazzoandLeggett1986
4-ADNT	lab	5	lab	42days	yellow nutsedge	Monocot	Cyperusesculentus	.	.	.	.	.	root	1520	.	.	PalazzoandLeggett1986
4-ADNT	lab	10	lab	42days	yellow nutsedge	Monocot	Cyperusesculentus	.	.	.	.	.	root	1793	.	.	PalazzoandLeggett1986
4-ADNT	lab	20	lab	42days	yellow nutsedge	Monocot	Cyperusesculentus	.	.	.	.	.	root	2180	.	.	PalazzoandLeggett1986
4-ADNT	lab	0	lab	42days	yellow nutsedge	Monocot	Cyperusesculentus	.	.	.	.	.	root	0	.	.	PalazzoandLeggett1986
4-ADNT	lab	5	lab	42days	yellow nutsedge	Monocot	Cyperusesculentus	.	.	.	.	.	root	60	.	.	PalazzoandLeggett1986
4-ADNT	lab	10	lab	42days	yellow nutsedge	Monocot	Cyperusesculentus	.	.	.	.	.	root	306	.	.	PalazzoandLeggett1986
4-ADNT	lab	20	lab	42days	yellow nutsedge	Monocot	Cyperusesculentus	.	.	.	.	.	root	238	.	.	PalazzoandLeggett1986
4-ADNT	Iowa	8	field	resident	arrow head	Dicot	Saggitariacalycina	.	.	.	0.5	U	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	20	field	resident	blacklocust	Dicot	Robiniapseudo-acacia	.	.	.	6.7	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	111	field	resident	blacklocust	Dicot	Robiniapseudo-acacia	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	144-2	field	resident	blacklocust	Dicot	Robiniapseudo-acacia	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	112-1	field	resident	milkweed	Dicot	Asclepiassyriaca	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	9	field	resident	Corn	Monocot	Zeamays	.	.	.	0.5	U	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	10	field	resident	Corn	Monocot	Zeamays	.	.	.	0.5	U	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	11	field	resident	Corn	Monocot	Zeamays	.	.	.	0.5	U	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	101	field	resident	Corn	Monocot	Zeamays	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	102	field	resident	Corn	Monocot	Zeamays	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	103	field	resident	Corn	Monocot	Zeamays	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	14	field	resident	goldenrod	Dicot	Solidagocanadensis	.	.	.	0.5	U	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	18	field	resident	goldenrod	Dicot	Solidagocanadensis	.	.	.	0.8	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	109	field	resident	goldenrod	Dicot	Solidagocanadensis	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	112-2	field	resident	goldenrod	Dicot	Solidagocanadensis	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	114-1	field	resident	goldenrod	Dicot	Solidagocanadensis	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	19-2	field	resident	goldenrod	Dicot	Solidagocanadensis	.	.	.	0.5	U	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	5	field	resident	Pigweed	Dicot	Amaranthussp.	.	.	.	0.5	U	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	106	field	resident	Pigweed	Dicot	Amaranthussp.	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	21	field	resident	Ragweed	Dicot	Ambrosiaartemisiifolia	.	.	.	0.5	U	leaf/stem	10.7	.	.	Schneider_et_al_1995
4-ADNT	Iowa	107	field	resident	Ragweed	Dicot	Ambrosiaartemisiifolia	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	108	field	resident	Ragweed	Dicot	Ambrosiaartemisiifolia	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	113	field	resident	redcedar	Gymnosperm	Juniperusviginiana	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	12	field	resident	reedcanarygrass	Monocot	Phalarisarundinacea	.	.	.	0.5	U	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	17	field	resident	reedcanarygrass	Monocot	Phalarisarundinacea	.	.	.	0.5	U	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	110	field	resident	reedcanarygrass	Monocot	Phalarisarundinacea	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	19-1	field	resident	reedcanarygrass	Monocot	Phalarisarundinacea	.	.	.	0.5	U	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	1	field	resident	smartweed	Dicot	Polygonumsp.	.	.	.	0.5	U	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	104	field	resident	smartweed	Dicot	Polygonumsp.	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	4	field	resident	smoothbromegrass	Monocot	Bromusinermis	.	.	.	0.5	U	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	105	field	resident	smoothbromegrass	Monocot	Bromusinermis	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	112-3	field	resident	sunflower	Dicot	Helianthusnutallii	.	.	.	.	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	8	field	resident	arrow head	Dicot	Saggitariacalycina	.	.	.	0.5	U	root	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	20	field	resident	blacklocust	Dicot	Robiniapseudo-acacia	.	.	.	6.7	.	root	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	112-1	field	resident	milkweed	Dicot	Asclepiassyriaca	.	.	.	.	.	root	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	101	field	resident	Corn	Monocot	Zeamays	.	.	.	.	.	root	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	102	field	resident	Corn	Monocot	Zeamays	.	.	.	.	.	root	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	103	field	resident	Corn	Monocot	Zeamays	.	.	.	.	.	root	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	14	field	resident	goldenrod	Dicot	Solidagocanadensis	.	.	.	0.5	U	root	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	18	field	resident	goldenrod	Dicot	Solidagocanadensis	.	.	.	0.8	.	root	0.5	U	.	Schneider_et_al_1995

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
4-ADNT	Iowa	109	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	.	.	root	290	.	.	Schneider_et_al_1995
4-ADNT	Iowa	112-2	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	.	.	root	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	19-2	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	0.5	U	root	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	5	field	resident	Pigweed	Dicot	*Amaranthussp.*	.	.	.	0.5	U	root	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	106	field	resident	Pigweed	Dicot	*Amaranthussp.*	.	.	.	.	.	root	2.8	.	.	Schneider_et_al_1995
4-ADNT	Iowa	21	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	.	.	.	0.5	U	root	33.3	.	.	Schneider_et_al_1995
4-ADNT	Iowa	107	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	.	.	.	.	.	root	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	108	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	.	.	.	.	.	root	18.1	.	.	Schneider_et_al_1995
4-ADNT	Iowa	17	field	resident	reedcanarygrass	Monocot	Phalarisarundinacea	.	.	.	0.5	U	root	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	110	field	resident	reedcanarygrass	Monocot	*Phalarisarundinacea*	.	.	.	.	.	root	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	19-1	field	resident	reedcanarygrass	Monocot	Phalarisarundinacea	.	.	.	0.5	U	root	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	1	field	resident	smartweed	Dicot	*Polygonumsp.*	.	.	.	0.5	U	root	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	104	field	resident	smartweed	Dicot	*Polygonumsp.*	.	.	.	.	.	root	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	4	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	0.5	U	root	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	105	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	.	.	root	10	.	.	Schneider_et_al_1995
4-ADNT	Iowa	112-3	field	resident	sunflower	Dicot	*Helianthusnutallii*	.	.	.	.	.	root	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	101	field	resident	Corn	Monocot	*Zeamays*	.	.	.	.	.	seed	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	102	field	resident	Corn	Monocot	*Zeamays*	.	.	.	.	.	seed	0.5	U	.	Schneider_et_al_1995
4-ADNT	Iowa	103	field	resident	Corn	Monocot	*Zeamays*	.	.	.	.	.	seed	0.5	U	.	Schneider_et_al_1995
4-ADNT	Illinois	13	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	5340	.	root	0.2	U	.	Zellmer_et_al_1995
4-ADNT	Illinois	14	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	3350	.	root	0.2	U	.	Zellmer_et_al_1995
4-ADNT	Illinois	4	field	resident	bluevervain	Monocot	*Verbenahastata*	.	.	.	1.5	.	root	0.2	U	.	Zellmer_et_al_1995
4-ADNT	Illinois	10	field	resident	chicory	Dicot	*Cichoriumintybus*	.	.	.	3360	.	root	0.2	U	.	Zellmer_et_al_1995
4-ADNT	Illinois	14	field	resident	chicory	Dicot	*Cichoriumintybus*	.	.	.	3350	.	root	0.2	U	.	Zellmer_et_al_1995
4-ADNT	Illinois	15	field	resident	chicory	Dicot	*Cichoriumintybus*	.	.	.	202	.	root	0.2	U	.	Zellmer_et_al_1995
4-ADNT	Illinois	5	field	resident	groundcherry	Monocot	*Physalisheterophylla*	.	.	.	1.6	.	root	0.2	U	.	Zellmer_et_al_1995
4-ADNT	Illinois	1	field	resident	milkweed	Dicot	*Asciepiassyriaca*	.	.	.	0.08	U	root	0.2	U	.	Zellmer_et_al_1995
4-ADNT	Illinois	3	field	resident	milkweed	Dicot	*Asciepiassyriaca*	.	.	.	1	.	root	0.2	U	.	Zellmer_et_al_1995
4-ADNT	Illinois	8	field	resident	milkweed	Dicot	*Asciepiassyriaca*	.	.	.	278	.	root	0.2	U	.	Zellmer_et_al_1995
4-ADNT	Illinois	14	field	resident	milkweed	Dicot	*Asciepiassyriaca*	.	.	.	3350	.	root	0.2	U	.	Zellmer_et_al_1995
4-ADNT	Illinois	2	field	resident	commonteasel	Dicot	*Dipsacussylvestris*	.	.	.	0.08	U	root	0.2	U	.	Zellmer_et_al_1995
4-ADNT	Illinois	6	field	resident	commonteasel	Dicot	*Dipsacussylvestris*	.	.	.	6260	.	root	2.12	.	.	Zellmer_et_al_1995
4-ADNT	Illinois	7	field	resident	commonteasel	Dicot	*Dipsacussylvestris*	.	.	.	492	.	root	0.57	.	.	Zellmer_et_al_1995
4-ADNT	Illinois	12	field	resident	commonteasel	Dicot	*Dipsacussylvestris*	.	.	.	39350	.	root	0.2	U	.	Zellmer_et_al_1995
4-ADNT	Illinois	3	field	resident	falseboneset	Dicot	*Kuhniaeupatorioides*	.	.	.	0.08	U	root	0.2	U	.	Zellmer_et_al_1995
4-ADNT	Illinois	10	field	resident	QueenAnne'slace	Dicot	*Daucuscarota*	.	.	.	3360	.	root	0.2	U	.	Zellmer_et_al_1995
4-ADNT	Illinois	15	field	resident	QueenAnne'slace	Dicot	*Daucuscarota*	.	.	.	202	.	root	0.2	U	.	Zellmer_et_al_1995
4-ADNT	Illinois	1	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	0.08	U	root	0.2	U	.	Zellmer_et_al_1995
4-ADNT	Illinois	2	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	0.08	U	root	0.2	U	.	Zellmer_et_al_1995
4-ADNT	Illinois	3	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	1	.	root	0.2	U	.	Zellmer_et_al_1995
4-ADNT	Illinois	4	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	1.5	.	root	0.2	U	.	Zellmer_et_al_1995
4-ADNT	Illinois	5	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	1.6	.	root	0.2	U	.	Zellmer_et_al_1995
4-ADNT	Illinois	6	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	6260	.	root	4.29	.	.	Zellmer_et_al_1995
4-ADNT	Illinois	7	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	492	.	root	0.63	.	.	Zellmer_et_al_1995
4-ADNT	Illinois	8	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	278	.	root	0.88	.	.	Zellmer_et_al_1995
4-ADNT	Illinois	9	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	5840	.	root	5.71	.	.	Zellmer_et_al_1995
4-ADNT	Illinois	11	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	3410	.	root	0.2	U	.	Zellmer_et_al_1995
4-ADNT	Illinois	12	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	39350	.	root	3.72	.	.	Zellmer_et_al_1995
4-ADNT	Illinois	13	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	5340	.	root	2.74	.	.	Zellmer_et_al_1995
4-ADNT	Illinois	14	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	3350	.	root	1.55	.	.	Zellmer_et_al_1995
Ace/Fluorene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.01464	.	leaf/stem	0.092	.	.	WildandJones1992
Ace/Fluorene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.04464	.	leaf/stem	0.082	.	.	WildandJones1992
Ace/Fluorene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.14904	.	leaf/stem	0.079	.	.	WildandJones1992
Ace/Fluorene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.01464	.	root	0.0151	.	.	WildandJones1992

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
Ace/Fluorene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.04464	.	root	0.0209	.	.	WildandJones1992
Ace/Fluorene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.14904	.	root	0.0141	.	.	WildandJones1992
acenaphthene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.17	.	leaf/stem	.	.	.	Kipopoulouetal.1999
acenaphthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.17	.	leaf/stem	.	.	.	Kipopoulouetal.1999
acenaphthene	.	.	.	.	endive	.	.	.	.	.	0.17	.	leaf/stem	.	.	.	Kipopoulouetal.1999
acenaphthene	.	.	.	.	leek	.	.	.	.	.	0.17	.	leaf/stem	.	.	.	Kipopoulouetal.1999
acenaphthene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.17	.	leaf/stem	.	.	.	Kipopoulouetal.1999
acenaphthene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.17	.	root	.	.	.	Kipopoulouetal.1999
acenaphthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.17	.	root	.	.	.	Kipopoulouetal.1999
acenaphthene	.	.	.	.	endive	.	.	.	.	.	0.17	.	root	.	.	.	Kipopoulouetal.1999
acenaphthene	.	.	.	.	leek	.	.	.	.	.	0.17	.	root	.	.	.	Kipopoulouetal.1999
acenaphthene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.17	.	root	.	.	.	Kipopoulouetal.1999
Ag	Oklahoma	TRAP2	field	resident	Greenbriar	Monocot	*Smilaxbona-nox*	6	.	31.7	2.1	.	seed	2.1	.	.	PTI1995
Ag	Oklahoma	GRID1	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7.1	.	21.6	1	.	seed	0.05	.	.	PTI1995
Ag	Oklahoma	GRID2	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.1	.	36.3	6.9	.	seed	0.04	.	.	PTI1995
Ag	Oklahoma	GRID3	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.6	.	30.7	3	.	seed	0.04	.	.	PTI1995
Ag	Oklahoma	GRID1	field	resident	Millet	Monocot	*Panicumvirgatum*	7.1	.	21.6	1	.	seed	0.04	.	.	PTI1995
Ag	Oklahoma	GRID2	field	resident	Millet	Monocot	*Panicumvirgatum*	6.1	.	36.3	6.9	.	seed	0.04	.	.	PTI1995
Ag	Oklahoma	GRID4	field	resident	Millet	Monocot	*Panicumvirgatum*	5.95	.	20.95	2.9	.	seed	0.02	.	.	PTI1995
Ag	Oklahoma	GRID2	field	resident	Pigweed	Dicot	*Amaranthuspalmeri*	6.1	.	36.3	6.9	.	seed	0.09	.	.	PTI1995
Ag	Oklahoma	GRID1	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	7.1	.	21.6	1	.	seed	0.04	.	.	PTI1995
Ag	Oklahoma	GRID3	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.6	.	30.7	3	.	seed	0.08	.	.	PTI1995
Ag	Oklahoma	GRID4	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	5.95	.	20.95	2.9	.	seed	0.02	.	.	PTI1995
Al	Oklahoma	GRID3	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.6	.	30.7	12200	.	seed	34	J	.	PTI1995
Al	Oklahoma	GRID4	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	5.95	.	20.95	14550	.	seed	27	J	.	PTI1995
Al	Oklahoma	TRAP1	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.4	.	14.1	16100	.	seed	16100	J	.	PTI1995
Al	Oklahoma	TRAP2	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6	.	31.7	13600	.	seed	13600	J	.	PTI1995
Al	Oklahoma	TRAP2	field	resident	Greenbriar	Monocot	*Smilaxbona-nox*	6	.	31.7	13600	.	seed	13600	J	.	PTI1995
Al	Oklahoma	GRID1	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7.1	.	21.6	16400	.	seed	50	J	.	PTI1995
Al	Oklahoma	GRID2	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.1	.	36.3	14700	.	seed	46	J	.	PTI1995
Al	Oklahoma	GRID3	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.6	.	30.7	12200	.	seed	50	J	.	PTI1995
Al	Oklahoma	TERA	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7	.	32.6	13750	.	seed	13750	.	.	PTI1995
Al	Oklahoma	TERB	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.5	.	20.3	16500	.	seed	16500	.	.	PTI1995
Al	Oklahoma	TERC	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.8	.	18.8	21050	.	seed	21050	J	.	PTI1995
Al	Oklahoma	GRID1	field	resident	Millet	Monocot	*Panicumvirgatum*	7.1	.	21.6	16400	.	seed	93	J	.	PTI1995
Al	Oklahoma	GRID2	field	resident	Millet	Monocot	*Panicumvirgatum*	6.1	.	36.3	14700	.	seed	125	J	.	PTI1995
Al	Oklahoma	GRID4	field	resident	Millet	Monocot	*Panicumvirgatum*	5.95	.	20.95	14550	.	seed	24	J	.	PTI1995
Al	Oklahoma	TERA	field	resident	Millet	Monocot	*Panicumvirgatum*	7	.	32.6	13750	.	seed	13750	.	.	PTI1995
Al	Oklahoma	TERB	field	resident	Millet	Monocot	*Panicumvirgatum*	6.5	.	20.3	16500	.	seed	16500	.	.	PTI1995
Al	Oklahoma	TERC	field	resident	Millet	Monocot	*Panicumvirgatum*	6.8	.	18.8	21050	.	seed	21050	J	.	PTI1995
Al	Oklahoma	GRID2	field	resident	Pigweed	Dicot	*Amaranthuspalmeri*	6.1	.	36.3	14700	.	seed	75	J	.	PTI1995
Al	Oklahoma	GRID1	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	7.1	.	21.6	16400	.	seed	89	J	.	PTI1995
Al	Oklahoma	GRID3	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.6	.	30.7	12200	.	seed	47	J	.	PTI1995
Al	Oklahoma	GRID4	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	5.95	.	20.95	14550	.	seed	46	J	.	PTI1995
Al	Oklahoma	TERA	field	resident	Ragweed	Dicot	*Ambrosiapsilostachya*	7	.	32.6	13750	.	seed	13750	.	.	PTI1995
Al	Oklahoma	TERB	field	resident	Ragweed	Dicot	*Ambrosiapsilostachya*	6.5	.	20.3	16500	.	seed	16500	.	.	PTI1995
Al	Oklahoma	TERC	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.8	.	18.8	21050	.	seed	21050	J	.	PTI1995
Al	Oklahoma	TRAP1	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.4	.	14.1	16100	.	seed	16100	.	.	PTI1995
Al	Oklahoma	TRAP1	field	resident	Ragweed	Dicot	*Ambrosiatrifida*	6.4	.	14.1	16100	.	seed	16100	.	.	PTI1995
Al	Oklahoma	TRAP2	field	resident	Ragweed	Dicot	*Ambrosiatrifida*	6	.	31.7	13600	.	seed	13600	J	.	PTI1995
Al	Canada	.	field	resident	Blueberry	Dicot	*Vacciniumangustifolium*	.	.	.	56000	.	leaf	190	.	64	SheppardandEvenden1990
Anthracene	.	.	.	.	soybean	Dicot	*Glycinemax*	.	.	.	0.01	.	leaf/stem	0.031	.	.	Edwardsetal.1982
Anthracene	.	.	.	.	soybean	Dicot	*Glycinemax*	.	.	.	0.014	.	leaf/stem	0.014	.	.	Edwardsetal.1982
Anthracene	.	.	.	.	soybean	Dicot	*Glycinemax*	.	.	.	0.01	.	root	0.125	.	.	Edwardsetal.1982

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
Anthracene	.	.	.	.	soybean	Dicot	*Glycinemax*	.	.	.	0.014	.	root	0.118	.	.	Edw ardsetal.1982
Anthracene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.0006	.	leaf/stem	0.0006	.	.	Kipopoulouetal.1999
Anthracene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0006	.	leaf/stem	.	.	.	Kipopoulouetal.1999
Anthracene	.	.	.	.	endive	.	.	.	.	.	0.0006	.	leaf/stem	0.0012	.	.	Kipopoulouetal.1999
Anthracene	.	.	.	.	leek	.	.	.	.	.	0.0006	.	leaf/stem	0.00047	.	.	Kipopoulouetal.1999
Anthracene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.0006	.	leaf/stem	0.0014	.	.	Kipopoulouetal.1999
Anthracene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.0006	.	root	.	.	.	Kipopoulouetal.1999
Anthracene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0006	.	root	0.00084	.	.	Kipopoulouetal.1999
Anthracene	.	.	.	.	endive	.	.	.	.	.	0.0006	.	root	.	.	.	Kipopoulouetal.1999
Anthracene	.	.	.	.	leek	.	.	.	.	.	0.0006	.	root	.	.	.	Kipopoulouetal.1999
Anthracene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.0006	.	root	.	.	.	Kipopoulouetal.1999
Anthracene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.002013	.	leaf/stem	0.001	.	.	WildandJones1992
Anthracene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.006138	.	leaf/stem	0.001	.	.	WildandJones1992
Anthracene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.020493	.	leaf/stem	0	.	.	WildandJones1992
Anthracene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.002013	.	root	0.0001	.	.	WildandJones1992
Anthracene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.006138	.	root	0.0002	.	.	WildandJones1992
Anthracene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.020493	.	root	0.0001	.	.	WildandJones1992
As	Maryland	1	field	resident	CommonReed	Monocot	*Phragmitesaustralis*	3	.	.	13	.	leaf	.	U	.	Beyeretal.1990
As	Delaw are	2	field	resident	CommonReed	Monocot	*Phragmitesaustralis*	5.2	.	.	10	.	leaf	.	U	.	Beyeretal.1990
As	Maryland	3	field	resident	CommonReed	Monocot	*Phragmitesaustralis*	3.1	.	.	7.8	.	leaf	.	U	.	Beyeretal.1990
As	Pennsylvania	4	field	resident	CommonReed	Monocot	*Phragmitesaustralis*	*6.3*	.	.	8.8	.	leaf	.	U	.	Beyeretal.1990
As	Maryland	5	field	resident	CommonReed	Monocot	*Phragmitesaustralis*	3.6	.	.	33	.	leaf	.	U	.	Beyeretal.1990
As	Montana	milltow n(reference)	field	resident	Grass	Monocot	.	.	.	.	7.7	.	leaf	2.1	.	1	Pascoeetal.1996
As	Montana	milltow n(reference)	field	resident	forb	Dicot	.	.	.	.	7.7	.	leaf/stem	0.45	.	2	Pascoeetal.1996
As	Montana	milltow n	field	resident	Grass	Monocot	.	.	.	.	67.1	.	leaf	6.7	.	4	Pascoeetal.1996
As	Montana	milltow n	field	resident	forb	Dicot	.	.	.	.	67.1	.	leaf/stem	1.1	.	20	Pascoeetal.1996
As	Wyoming	Reference	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	3.57	.	leaf	0.1	.	.	RamirezandRogers2000
As	Wyoming	Reference	field	resident	Brome	Monocot	*Bromussp.*	.	.	.	3.57	.	leaf	0.08	.	.	RamirezandRogers2000
As	Wyoming	StudyArea	field	resident	Dandelion	Dicot	*Taraxacumofficinale*	.	.	.	3.96	.	leaf	0.2	.	.	RamirezandRogers2000
As	Wyoming	StudyArea	field	resident	FoxtailBarley	Dicot	*Hordiumjubatum*	.	.	.	3.96	.	leaf	0.05	.	.	RamirezandRogers2000
As	Wyoming	Reference	field	resident	KentuckyBluegrass	Monocot	*PoaPratensis*	.	.	.	3.57	.	leaf	0.045	.	.	RamirezandRogers2000
As	Wyoming	StudyArea	field	resident	Pondw eed	Monocot	*Potamogetonsp*	.	.	.	0.00	.	leaf	2.66	.	.	RamirezandRogers2000
As	California	Kesterson	field	248days	Grass	Monocot	*Elytrigiapontica*	7.8	.	14	0.8	.	leaf/stem	0.5	.	.	Retanaetal.1993
As	California	Kesterson	field	248days	Grass	Monocot	*Oryzopsishymenoides*	7.8	.	14	0.8	.	leaf/stem	0.3	.	.	Retanaetal.1993
As	California	Kesterson	field	248days	Grass	Monocot	*Sporobolusairoides*	7.8	.	14	0.8	.	leaf/stem	0.5	.	.	Retanaetal.1993
As	California	Kesterson	field	248days	Seaccumulator	Dicot	*Astragalusbisulcatus*	7.8	.	14	0.8	.	leaf/stem	0.2	.	.	Retanaetal.1993
As	California	Kesterson	field	248days	Seaccumulator	Dicot	*Astragalusracemosus*	7.8	.	14	0.8	.	leaf/stem	0.4	.	.	Retanaetal.1993
As	California	Kesterson	field	248days	Grass	Monocot	*Elytrigiapontica*	7.8	.	14	0.8	.	root	0.6	.	.	Retanaetal.1993
As	California	Kesterson	field	248days	Grass	Monocot	*Oryzopsishymenoides*	7.8	.	14	0.8	.	root	1.6	.	.	Retanaetal.1993
As	California	Kesterson	field	248days	Grass	Monocot	*Sporobolusairoides*	7.8	.	14	0.8	.	root	0.4	.	.	Retanaetal.1993
As	California	Kesterson	field	248days	Seaccumulator	Dicot	*Astragalusbisulcatus*	7.8	.	14	0.8	.	root	0.9	.	.	Retanaetal.1993
As	California	Kesterson	field	248days	Seaccumulator	Dicot	*Astragalusracemosus*	7.8	.	14	0.8	.	root	1	.	.	Retanaetal.1993
B	California	Kesterson	field	resident	BirdfootTrefoil	Dicot	*Lotuscorniculatus*	.	.	.	48	.	leaf/stem	117	.	.	Banuelosetal.1999
B	California	Kesterson	field	resident	Mustard	Dicot	*Brassicajuncea*	.	.	.	48	.	leaf/stem	290	.	.	Banuelosetal.1999
B	California	Kesterson	field	resident	Rose-Mallow	Dicot	*Hibiscuscanabinus*	.	.	.	48	.	leaf/stem	760	.	.	Banuelosetal.1999
B	California	Kesterson	field	resident	TallFescue	Monocot	*Festucaarundinacea*	.	.	.	48	.	leaf/stem	100	.	.	Banuelosetal.1999
B	California	Kesterson	field	resident	BirdfootTrefoil	Dicot	*Lotuscorniculatus*	.	.	.	48	.	root	112	.	.	Banuelosetal.1999
B	California	Kesterson	field	resident	Rose-Mallow	Dicot	*Hibiscuscanabinus*	.	.	.	48	.	root	140	.	.	Banuelosetal.1999
B	California	Kesterson	field	resident	TallFescue	Monocot	*Festucaarundinacea*	.	.	.	48	.	root	113	.	.	Banuelosetal.1999
B	California	Kesterson	field	248days	Grass	Monocot	*Elytrigiapontica*	7.8	.	14	39.2	.	leaf/stem	224	.	.	Retanaetal.1993
B	California	Kesterson	field	248days	Grass	Monocot	*Oryzopsishymenoides*	7.8	.	14	39.2	.	leaf/stem	710	.	.	Retanaetal.1993
B	California	Kesterson	field	248days	Grass	Monocot	*Sporobolusairoides*	7.8	.	14	39.2	.	leaf/stem	66	.	.	Retanaetal.1993
B	California	Kesterson	field	248days	Seaccumulator	Dicot	*Astragalusbisulcatus*	7.8	.	14	39.2	.	leaf/stem	262	.	.	Retanaetal.1993
B	California	Kesterson	field	248days	Seaccumulator	Dicot	*Astragalusracemosus*	7.8	.	14	39.2	.	leaf/stem	146	.	.	Retanaetal.1993

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
B	California	Kesterson	field	248days	Grass	Monocot	*Elytrigiapontica*	7.8	.	14	39.2	.	root	13	.	.	Retanaetal.1993
B	California	Kesterson	field	248days	Grass	Monocot	*Oryzopsishymenoides*	7.8	.	14	39.2	.	root	67	.	.	Retanaetal.1993
B	California	Kesterson	field	248days	Grass	Monocot	*Sporobolusairoides*	7.8	.	14	39.2	.	root	14	.	.	Retanaetal.1993
B	California	Kesterson	field	248days	Seaccumulator	Dicot	*Astragalusbisulcatus*	7.8	.	14	39.2	.	root	46	.	.	Retanaetal.1993
B	California	Kesterson	field	248days	Seaccumulator	Dicot	*Astragalusracemosus*	7.8	.	14	39.2	.	root	44	.	.	Retanaetal.1993
Ba	Virginia	.	field	resident	vegetation	.	.	.	.	.	104.2	.	various	29.8	.	13	Hopeetal.1996
Ba	Oklahoma	GRID3	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.6	.	30.7	92.2	.	seed	20.3	.	.	PTI1995
Ba	Oklahoma	GRID4	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	5.95	.	20.95	164	.	seed	18.4	J	.	PTI1995
Ba	Oklahoma	TRAP1	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.4	.	14.1	176	.	seed	176	J	.	PTI1995
Ba	Oklahoma	TRAP2	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6	.	31.7	157	.	seed	157	J	.	PTI1995
Ba	Oklahoma	TRAP2	field	resident	Greenbriar	Monocot	*Smilaxbona-nox*	6	.	31.7	157	.	seed	157	J	.	PTI1995
Ba	Oklahoma	GRID1	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7.1	.	21.6	151	.	seed	8.4	J	.	PTI1995
Ba	Oklahoma	GRID2	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.1	.	36.3	160	.	seed	16.8	.	.	PTI1995
Ba	Oklahoma	GRID3	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.6	.	30.7	92.2	.	seed	11.5	.	.	PTI1995
Ba	Oklahoma	TERA	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7	.	32.6	103.6	.	seed	103.6	.	.	PTI1995
Ba	Oklahoma	TERB	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.5	.	20.3	119.5	.	seed	119.5	.	.	PTI1995
Ba	Oklahoma	TERC	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.8	.	18.8	216	.	seed	216	.	.	PTI1995
Ba	Oklahoma	GRID1	field	resident	Millet	Monocot	*Panicumvirgatum*	7.1	.	21.6	151	.	seed	2	J	.	PTI1995
Ba	Oklahoma	GRID2	field	resident	Millet	Monocot	*Panicumvirgatum*	6.1	.	36.3	160	.	seed	2.8	.	.	PTI1995
Ba	Oklahoma	GRID4	field	resident	Millet	Monocot	*Panicumvirgatum*	5.95	.	20.95	164	.	seed	10.2	J	.	PTI1995
Ba	Oklahoma	TERA	field	resident	Millet	Monocot	*Panicumvirgatum*	7	.	32.6	103.6	.	seed	103.6	.	.	PTI1995
Ba	Oklahoma	TERB	field	resident	Millet	Monocot	*Panicumvirgatum*	6.5	.	20.3	119.5	.	seed	119.5	.	.	PTI1995
Ba	Oklahoma	TERC	field	resident	Millet	Monocot	*Panicumvirgatum*	6.8	.	18.8	216	.	seed	216	.	.	PTI1995
Ba	Oklahoma	GRID2	field	resident	Pigw eed	Dicot	*Amaranthuspalmeri*	6.1	.	36.3	160	.	seed	51.6	.	.	PTI1995
Ba	Oklahoma	GRID1	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	7.1	.	21.6	151	.	seed	33	J	.	PTI1995
Ba	Oklahoma	GRID3	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	6.6	.	30.7	92.2	.	seed	54.5	.	.	PTI1995
Ba	Oklahoma	GRID4	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	5.95	.	20.95	164	.	seed	72.1	J	.	PTI1995
Ba	Oklahoma	TERA	field	resident	Ragw eed	Dicot	*Ambrosiapsilostachya*	7	.	32.6	103.6	.	seed	103.6	.	.	PTI1995
Ba	Oklahoma	TERB	field	resident	Ragw eed	Dicot	*Ambrosiapsilostachya*	6.5	.	20.3	119.5	.	seed	119.5	.	.	PTI1995
Ba	Oklahoma	TERC	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	6.8	.	18.8	216	.	seed	216	.	.	PTI1995
Ba	Oklahoma	TRAP1	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	6.4	.	14.1	176	.	seed	176	.	.	PTI1995
Ba	Oklahoma	TRAP1	field	resident	Ragw eed	Dicot	*Ambrosiatrifida*	6.4	.	14.1	176	.	seed	176	.	.	PTI1995
Ba	Oklahoma	TRAP2	field	resident	Ragw eed	Dicot	*Ambrosiatrifida*	6	.	31.7	157	.	seed	157	J	.	PTI1995
Ba	Wyoming	Reference	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	76.99	.	leaf	8.5	.	.	RamirezandRogers2000
Ba	Wyoming	Reference	field	resident	Brome	Monocot	*Bromussp.*	.	.	.	76.99	.	leaf	30.63	.	.	RamirezandRogers2000
Ba	Wyoming	StudyArea	field	resident	Brome	Monocot	*Bromussp.*	.	.	.	113.81	.	leaf	10.82	.	.	RamirezandRogers2000
Ba	Wyoming	StudyArea	field	resident	Dandelion	Dicot	*Taraxacumofficinale*	.	.	.	113.81	.	leaf	4.4	.	.	RamirezandRogers2000
Ba	Wyoming	StudyArea	field	resident	FoxtailBarley	Dicot	*Hordiumjubatum*	.	.	.	113.81	.	leaf	7.80	.	.	RamirezandRogers2000
Ba	Wyoming	Reference	field	resident	KentuckyBluegrass	Monocot	*PoaPratensis*	.	.	.	76.99	.	leaf	14	.	.	RamirezandRogers2000
Ba	Wyoming	StudyArea	field	resident	Pondw eed	Monocot	*Potamogetonsp*	.	.	.	0.16	.	leaf	219.54	.	.	RamirezandRogers2000
Ba	Canada	.	field	resident	Blueberry	Dicot	*Vacciniumangustifolium*	.	.	.	630	.	leaf	28	.	64	SheppardandEvenden1990
Benz/Chrysene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.01037	.	leaf/stem	0.008	.	.	WildandJones1992
Benz/Chrysene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.03162	.	leaf/stem	0.004	.	.	WildandJones1992
Benz/Chrysene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.10557	.	leaf/stem	0.003	.	.	WildandJones1992
Benz/Chrysene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.01037	.	root	0.0001	.	.	WildandJones1992
Benz/Chrysene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.03162	.	root	0.0016	.	.	WildandJones1992
Benz/Chrysene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.10557	.	root	0.0011	.	.	WildandJones1992
benzo(a)anthracene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.0054	.	leaf/stem	.	.	.	Kipopoulouetal.1999
benzo(a)anthracene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0054	.	leaf/stem	.	.	.	Kipopoulouetal.1999
benzo(a)anthracene	.	.	.	.	endive	.	.	.	.	.	0.0054	.	leaf/stem	.	.	.	Kipopoulouetal.1999
benzo(a)anthracene	.	.	.	.	leek	.	.	.	.	.	0.0054	.	leaf/stem	.	.	.	Kipopoulouetal.1999
benzo(a)anthracene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.0054	.	leaf/stem	0.0029	.	.	Kipopoulouetal.1999
benzo(a)anthracene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.0054	.	root	.	.	.	Kipopoulouetal.1999
benzo(a)anthracene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0054	.	root	.	.	.	Kipopoulouetal.1999

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
benzo(a)anthracene	.	.	.	.	endive	.	.	.	.	.	0.0054	.	root	.	.	.	Kipopoulouetal.1999
benzo(a)anthracene	.	.	.	.	leek	.	.	.	.	.	0.0054	.	root	.	.	.	Kipopoulouetal.1999
benzo(a)anthracene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.0054	.	root	.	.	.	Kipopoulouetal.1999
Benzo(a)pyrene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.0024	.	leaf/stem	0.0001	.	.	Kipopoulouetal.1999
Benzo(a)pyrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0024	.	leaf/stem	.	.	.	Kipopoulouetal.1999
Benzo(a)pyrene	.	.	.	.	endive	.	.	.	.	.	0.0024	.	leaf/stem	0.00024	.	.	Kipopoulouetal.1999
Benzo(a)pyrene	.	.	.	.	leek	.	.	.	.	.	0.0024	.	leaf/stem	0.00015	.	.	Kipopoulouetal.1999
Benzo(a)pyrene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.0024	.	leaf/stem	0.00028	.	.	Kipopoulouetal.1999
Benzo(a)pyrene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.0024	.	root	.	.	.	Kipopoulouetal.1999
Benzo(a)pyrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0024	.	root	0.00011	.	.	Kipopoulouetal.1999
Benzo(a)pyrene	.	.	.	.	endive	.	.	.	.	.	0.0024	.	root	.	.	.	Kipopoulouetal.1999
Benzo(a)pyrene	.	.	.	.	leek	.	.	.	.	.	0.0024	.	root	.	.	.	Kipopoulouetal.1999
Benzo(a)pyrene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.0024	.	root	.	.	.	Kipopoulouetal.1999
Benzo(a)pyrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.005002	.	leaf/stem	0.001	.	.	WildandJones1992
Benzo(a)pyrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.015252	.	leaf/stem	0.001	.	.	WildandJones1992
Benzo(a)pyrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.050922	.	leaf/stem	0.001	.	.	WildandJones1992
Benzo(a)pyrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.005002	.	root	0.0011	.	.	WildandJones1992
Benzo(a)pyrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.015252	.	root	0.0013	.	.	WildandJones1992
Benzo(a)pyrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.050922	.	root	0.0006	.	.	WildandJones1992
Benzo(b)fluoranthene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.0025	.	leaf/stem	0.0002	.	.	Kipopoulouetal.1999
Benzo(b)fluoranthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0025	.	leaf/stem	.	.	.	Kipopoulouetal.1999
Benzo(b)fluoranthene	.	.	.	.	endive	.	.	.	.	.	0.0025	.	leaf/stem	0.0012	.	.	Kipopoulouetal.1999
Benzo(b)fluoranthene	.	.	.	.	leek	.	.	.	.	.	0.0025	.	leaf/stem	0.00045	.	.	Kipopoulouetal.1999
Benzo(b)fluoranthene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.0025	.	leaf/stem	0.0011	.	.	Kipopoulouetal.1999
Benzo(b)fluoranthene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.0025	.	root	.	.	.	Kipopoulouetal.1999
Benzo(b)fluoranthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0025	.	root	0.00025	.	.	Kipopoulouetal.1999
Benzo(b)fluoranthene	.	.	.	.	endive	.	.	.	.	.	0.0025	.	root	.	.	.	Kipopoulouetal.1999
Benzo(b)fluoranthene	.	.	.	.	leek	.	.	.	.	.	0.0025	.	root	.	.	.	Kipopoulouetal.1999
Benzo(b)fluoranthene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.0025	.	root	.	.	.	Kipopoulouetal.1999
Benzo(b)fluoranthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.006039	.	leaf/stem	0.001	.	.	WildandJones1992
Benzo(b)fluoranthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.018414	.	leaf/stem	0	.	.	WildandJones1992
Benzo(b)fluoranthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.061479	.	leaf/stem	0.001	.	.	WildandJones1992
Benzo(b)fluoranthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.006039	.	root	0.0001	.	.	WildandJones1992
Benzo(b)fluoranthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.018414	.	root	0	.	.	WildandJones1992
Benzo(b)fluoranthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.061479	.	root	0	.	.	WildandJones1992
benzo(e)pyrene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.0059	.	leaf/stem	0.0006	.	.	Kipopoulouetal.1999
benzo(e)pyrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0059	.	leaf/stem	.	.	.	Kipopoulouetal.1999
benzo(e)pyrene	.	.	.	.	endive	.	.	.	.	.	0.0059	.	leaf/stem	0.0013	.	.	Kipopoulouetal.1999
benzo(e)pyrene	.	.	.	.	leek	.	.	.	.	.	0.0059	.	leaf/stem	0.00094	.	.	Kipopoulouetal.1999
benzo(e)pyrene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.0059	.	leaf/stem	0.0016	.	.	Kipopoulouetal.1999
benzo(e)pyrene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.0059	.	root	.	.	.	Kipopoulouetal.1999
benzo(e)pyrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0059	.	root	0.0009	.	.	Kipopoulouetal.1999
benzo(e)pyrene	.	.	.	.	endive	.	.	.	.	.	0.0059	.	root	.	.	.	Kipopoulouetal.1999
benzo(e)pyrene	.	.	.	.	leek	.	.	.	.	.	0.0059	.	root	.	.	.	Kipopoulouetal.1999
benzo(e)pyrene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.0059	.	root	.	.	.	Kipopoulouetal.1999
Benzo(ghi)perylene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.0036	.	leaf/stem	0.00032	.	.	Kipopoulouetal.1999
Benzo(ghi)perylene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0036	.	leaf/stem	.	.	.	Kipopoulouetal.1999
Benzo(ghi)perylene	.	.	.	.	endive	.	.	.	.	.	0.0036	.	leaf/stem	0.00027	.	.	Kipopoulouetal.1999
Benzo(ghi)perylene	.	.	.	.	leek	.	.	.	.	.	0.0036	.	leaf/stem	0.00047	.	.	Kipopoulouetal.1999
Benzo(ghi)perylene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.0036	.	leaf/stem	0.00019	.	.	Kipopoulouetal.1999
Benzo(ghi)perylene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.0036	.	root	.	.	.	Kipopoulouetal.1999
Benzo(ghi)perylene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0036	.	root	0.00029	.	.	Kipopoulouetal.1999
Benzo(ghi)perylene	.	.	.	.	endive	.	.	.	.	.	0.0036	.	root	.	.	.	Kipopoulouetal.1999
Benzo(ghi)perylene	.	.	.	.	leek	.	.	.	.	.	0.0036	.	root	.	.	.	Kipopoulouetal.1999

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
Benzo(ghi)perylene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.0036	.	root	.	.	.	Kipopoulouetal.1999
Benzo(ghi)perylene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.01525	.	leaf/stem	0.02	.	.	WildandJones1992
Benzo(ghi)perylene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0465	.	leaf/stem	0.012	.	.	WildandJones1992
Benzo(ghi)perylene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.15525	.	leaf/stem	0.024	.	.	WildandJones1992
Benzo(ghi)perylene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.01525	.	root	0.0006	.	.	WildandJones1992
Benzo(ghi)perylene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0465	.	root	0	.	.	WildandJones1992
Benzo(ghi)perylene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.15525	.	root	0.0013	.	.	WildandJones1992
Benzo(k)fluoranthene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.001	.	leaf/stem	0.00008	.	.	Kipopoulouetal.1999
Benzo(k)fluoranthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.001	.	leaf/stem	.	.	.	Kipopoulouetal.1999
Benzo(k)fluoranthene	.	.	.	.	endive	.	.	.	.	.	0.001	.	leaf/stem	0.00036	.	.	Kipopoulouetal.1999
Benzo(k)fluoranthene	.	.	.	.	leek	.	.	.	.	.	0.001	.	leaf/stem	0.00017	.	.	Kipopoulouetal.1999
Benzo(k)fluoranthene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.001	.	leaf/stem	0.00034	.	.	Kipopoulouetal.1999
Benzo(k)fluoranthene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.001	.	root	.	.	.	Kipopoulouetal.1999
Benzo(k)fluoranthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.001	.	root	0.0001	.	.	Kipopoulouetal.1999
Benzo(k)fluoranthene	.	.	.	.	endive	.	.	.	.	.	0.001	.	root	.	.	.	Kipopoulouetal.1999
Benzo(k)fluoranthene	.	.	.	.	leek	.	.	.	.	.	0.001	.	root	.	.	.	Kipopoulouetal.1999
Benzo(k)fluoranthene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.001	.	root	.	.	.	Kipopoulouetal.1999
Benzo(k)fluoranthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.002928	.	leaf/stem	0	.	.	WildandJones1992
Benzo(k)fluoranthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.008928	.	leaf/stem	0	.	.	WildandJones1992
Benzo(k)fluoranthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.029808	.	leaf/stem	0	.	.	WildandJones1992
Benzo(k)fluoranthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.002928	.	root	0	.	.	WildandJones1992
Benzo(k)fluoranthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.008928	.	root	0	.	.	WildandJones1992
Benzo(k)fluoranthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.029808	.	root	0	.	.	WildandJones1992
Ca	Oklahoma	GRID3	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.6	.	30.7	1790	.	seed	8360	.	.	PTI1995
Ca	Oklahoma	GRID4	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	5.95	.	20.95	3715	.	seed	8400	J	.	PTI1995
Ca	Oklahoma	TRAP1	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.4	.	14.1	8380	.	seed	8380	J	.	PTI1995
Ca	Oklahoma	TRAP2	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6	.	31.7	4110	.	seed	4110	J	.	PTI1995
Ca	Oklahoma	TRAP2	field	resident	Greenbriar	Monocot	*Smilaxbona-nox*	6	.	31.7	4110	.	seed	4110	J	.	PTI1995
Ca	Oklahoma	GRID1	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7.1	.	21.6	26.6	.	seed	1.1	.	.	PTI1995
Ca	Oklahoma	GRID1	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7.1	.	21.6	13000	.	seed	1650	J	.	PTI1995
Ca	Oklahoma	GRID2	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.1	.	36.3	2500	.	seed	1490	.	.	PTI1995
Ca	Oklahoma	GRID3	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.6	.	30.7	1790	.	seed	1310	.	.	PTI1995
Ca	Oklahoma	TERA	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7	.	32.6	1950	.	seed	1950	.	.	PTI1995
Ca	Oklahoma	TERB	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.5	.	20.3	2195	.	seed	2195	.	.	PTI1995
Ca	Oklahoma	TERC	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.8	.	18.8	35770	.	seed	35770	.	.	PTI1995
Ca	Oklahoma	GRID1	field	resident	Millet	Monocot	*Panicumvirgatum*	7.1	.	21.6	13000	.	seed	3660	J	.	PTI1995
Ca	Oklahoma	GRID2	field	resident	Millet	Monocot	*Panicumvirgatum*	6.1	.	36.3	2500	.	seed	4400	.	.	PTI1995
Ca	Oklahoma	GRID4	field	resident	Millet	Monocot	*Panicumvirgatum*	5.95	.	20.95	3715	.	seed	1820	J	.	PTI1995
Ca	Oklahoma	TERA	field	resident	Millet	Monocot	*Panicumvirgatum*	7	.	32.6	1950	.	seed	1950	.	.	PTI1995
Ca	Oklahoma	TERB	field	resident	Millet	Monocot	*Panicumvirgatum*	6.5	.	20.3	2195	.	seed	2195	.	.	PTI1995
Ca	Oklahoma	TERC	field	resident	Millet	Monocot	*Panicumvirgatum*	6.8	.	18.8	35770	.	seed	35770	.	.	PTI1995
Ca	Oklahoma	GRID2	field	resident	Pigw eed	Dicot	*Amaranthuspalmeri*	6.1	.	36.3	2500	.	seed	7910	.	.	PTI1995
Ca	Oklahoma	GRID1	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	7.1	.	21.6	13000	.	seed	23700	J	.	PTI1995
Ca	Oklahoma	GRID3	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	6.6	.	30.7	1790	.	seed	19000	.	.	PTI1995
Ca	Oklahoma	GRID4	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	5.95	.	20.95	3715	.	seed	22000	J	.	PTI1995
Ca	Oklahoma	TERA	field	resident	Ragw eed	Dicot	*Ambrosiapsilostachya*	7	.	32.6	1950	.	seed	1950	.	.	PTI1995
Ca	Oklahoma	TERB	field	resident	Ragw eed	Dicot	*Ambrosiapsilostachya*	6.5	.	20.3	2195	.	seed	2195	.	.	PTI1995
Ca	Oklahoma	TERC	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	6.8	.	18.8	35770	.	seed	35770	.	.	PTI1995
Ca	Oklahoma	TRAP1	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	6.4	.	14.1	8380	.	seed	8380	.	.	PTI1995
Ca	Oklahoma	TRAP1	field	resident	Ragw eed	Dicot	*Ambrosiatrifida*	6.4	.	14.1	8380	.	seed	8380	.	.	PTI1995
Ca	Oklahoma	TRAP2	field	resident	Ragw eed	Dicot	*Ambrosiatrifida*	6	.	31.7	4110	.	seed	4110	J	.	PTI1995
Cd	California	Kesterson	field	resident	BirdfootTrefoil	Dicot	*Lotuscorniculatus*	.	.	.	7	.	leaf/stem	0.9	.	.	Banuelosetal.1999
Cd	California	Kesterson	field	resident	Mustard	Dicot	*Brassicajuncea*	.	.	.	7	.	leaf/stem	15	.	.	Banuelosetal.1999
Cd	California	Kesterson	field	resident	Rose-Mallow	Dicot	*Hibiscuscanabinus*	.	.	.	7	.	leaf/stem	24	.	.	Banuelosetal.1999

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
Cd	California	Kesterson	field	resident	TallFescue	Monocot	*Festucaarundinacea*	.	.	.	7	.	leaf/stem	0.9	.	.	Banuelosetal.1999
Cd	California	Kesterson	field	resident	BirdfootTrefoil	Dicot	*Lotuscorniculatus*	.	.	.	7	.	root	0.9	.	.	Banuelosetal.1999
Cd	California	Kesterson	field	resident	Mustard	Dicot	*Brassicajuncea*	.	.	.	7	.	root	12	.	.	Banuelosetal.1999
Cd	California	Kesterson	field	resident	Mustard	Dicot	*Brassicajuncea*	.	.	.	663.5	.	root	28	.	.	Banuelosetal.1999
Cd	California	Kesterson	field	resident	Mustard	Dicot	*Brassicajuncea*	.	.	.	0.9	.	root	0.4	.	.	Banuelosetal.1999
Cd	California	Kesterson	field	resident	Mustard	Dicot	*Brassicajuncea*	.	.	.	48	.	root	119	.	.	Banuelosetal.1999
Cd	California	Kesterson	field	resident	Rose-Mallow	Dicot	*Hibiscuscanabinus*	.	.	.	7	.	root	21	.	.	Banuelosetal.1999
Cd	California	Kesterson	field	resident	TallFescue	Monocot	*Festucaarundinacea*	.	.	.	663.5	.	root	27	.	.	Banuelosetal.1999
Cd	Bundaberg-Kolan	Kerman	lab	maturity	Bean	Dicot	*Phaselousvulgaris*	6.0	.	5.2	0.042	.	seed	0.032	.	2	Belletal.1997
Cd	Bundaberg-Kolan	Spearfelt	lab	maturity	Bean	Dicot	*Phaselousvulgaris*	6.0	.	5.2	0.042	.	seed	0.036	.	2	Belletal.1997
Cd	Bundaberg-Kolan	NC7	lab	maturity	peanut	Dicot	*Arachishypogaea*	6.0	.	5.2	0.042	.	seed	0.057	.	3	Belletal.1997
Cd	Bundaberg-Kolan	Streeton	lab	maturity	peanut	Dicot	*Arachishypogaea*	6.0	.	5.2	0.042	.	seed	0.061	.	3	Belletal.1997
Cd	Bundabergrotationtrial	Sirrius	field	maturity	Bean	Dicot	*Phaselousvulgaris*	6.5	.	2.9	0.058	.	seed	0.009	U	.	Belletal.1997
Cd	Bundaberg-Calavos	Sirrius	field	maturity	Bean	Dicot	*Phaselousvulgaris*	5.9	.	2.2	0.029	.	seed	0.033	.	.	Belletal.1997
Cd	Bundabergrotationtrial	DK689	field	resident	Corn	Monocot	*ZeaMays*	6.5	.	2.9	0.058	.	seed	0.009	U	.	Belletal.1997
Cd	Tullyrotationaltrial	Meringa	field	maturity	Cow pea	Dicot	*Vignasinensis*	5.4	.	2.7	0.010	.	seed	0.009	U	.	Belletal.1997
Cd	Ayrrotationtrial	Streeton	field	maturity	peanut	Dicot	*Arachishypogaea*	7.1	.	16.4	0.072	.	seed	0.055	.	.	Belletal.1997
Cd	Bundabergrotationtrial	Streeton	field	maturity	peanut	Dicot	*Arachishypogaea*	6.5	.	2.9	0.058	.	seed	0.101	.	.	Belletal.1997
Cd	Bundaberg-Calavos	Streeton	field	maturity	peanut	Dicot	*Arachishypogaea*	5.9	.	2.2	0.029	.	seed	0.348	.	.	Belletal.1997
Cd	Bundaberg-Kolan	Streeton	field	maturity	peanut	Dicot	*Arachishypogaea*	6.0	.	5.2	0.042	.	seed	0.178	.	.	Belletal.1997
Cd	Inghamrotationaltrial	Streeton	field	maturity	peanut	Dicot	*Arachishypogaea*	5.5	.	3.2	0.042	.	seed	0.083	.	.	Belletal.1997
Cd	Kingaroy	Streeton	field	maturity	peanut	Dicot	*Arachishypogaea*	5.9	.	8.1	0.053	.	seed	0.011	.	.	Belletal.1997
Cd	Mackayrotationtrial	Streeton	field	maturity	peanut	Dicot	*Arachishypogaea*	5.3	.	5.0	0.047	.	seed	0.060	.	.	Belletal.1997
Cd	Tullyrotationaltrial	Streeton	field	maturity	peanut	Dicot	*Arachishypogaea*	5.4	.	*2.7*	0.010	.	seed	0.082	.	.	Belletal.1997
Cd	Bundanberg-Kolan/Brow n	Streeton	lab	maturity	peanut	Dicot	*Arachishypogaea*	6.1	.	.	0.032	.	seed	0.094	.	.	Belletal.1997
Cd	Bundanberg-Kolan/Red	Streeton	lab	maturity	peanut	Dicot	*Arachishypogaea*	5.2	.	.	0.044	.	seed	0.185	.	.	Belletal.1997
Cd	Kingaroy	Streeton	lab	maturity	peanut	Dicot	*Arachishypogaea*	6.7	.	.	0.067	.	seed	0.007	.	.	Belletal.1997
Cd	Ayrrotationtrial	Leichardt	field	maturity	soybean	Dicot	*Glycinemax*	7.1	.	16.4	0.072	.	seed	0.019	.	.	Belletal.1997
Cd	Inghamrotationaltrial	Leichardt	field	maturity	soybean	Dicot	*Glycinemax*	5.5	.	3.2	0.042	.	seed	0.061	.	.	Belletal.1997
Cd	Mackayrotationtrial	Leichardt	field	maturity	soybean	Dicot	*Glycinemax*	5.3	.	5.0	0.047	.	seed	0.041	.	.	Belletal.1997
Cd	Tullyrotationaltrial	Leichardt	field	maturity	soybean	Dicot	*Glycinemax*	5.4	.	*2.7*	0.010	.	seed	0.022	.	.	Belletal.1997
Cd	Kingaroy	Manark	field	maturity	soybean	Dicot	*Glycinemax*	5.9	.	8.1	0.053	.	seed	0.021	.	.	Belletal.1997
Cd	Pennsylvania	Palmerton	field	resident	acorns/berries	Dicot	mixedfruitsandacorns	5.9	12	14	35	.	fruit/seed	1.2	.	3	Beyeretal.1985
Cd	Pennsylvania	BakeOvenKnob	field	resident	acorns/berries	Dicot	mixedfruitsandacorns	5	23	19	2.7	.	fruit/seed	0.6	.	4	Beyeretal.1985
Cd	Maryland	1	field	resident	CommonReed	Monocot	*Phragmitesaustralis*	3	.	.	0.7	.	leaf	.	U	.	Beyeretal.1990
Cd	Delaw are	2	field	resident	CommonReed	Monocot	*Phragmitesaustralis*	5.2	.	.	1.5	.	leaf	.	U	.	Beyeretal.1990
Cd	Maryland	3	field	resident	CommonReed	Monocot	*Phragmitesaustralis*	3.1	.	.	1	.	leaf	.	U	.	Beyeretal.1990
Cd	Pennsylvania	4	field	resident	CommonReed	Monocot	*Phragmitesaustralis*	*6.3*	.	.	0.62	.	leaf	.	U	.	Beyeretal.1990
Cd	Maryland	5	field	resident	CommonReed	Monocot	*Phragmitesaustralis*	3.6	.	.	1	.	leaf	.	U	.	Beyeretal.1990
Cd	Canada	Regina623	lab	7w eek	durumw heat	Monocot	*Triticumturgidum*	7.2	.	29.6	0.323	.	leaf	0.3849	.	.	Cieslinkietal.1996
Cd	Canada	ReginaDT627	lab	7w eek	durumw heat	Monocot	*Triticumturgidum*	7.2	.	29.6	0.323	.	leaf	0.3431	.	.	Cieslinkietal.1996
Cd	Canada	ReginaKyle	lab	7w eek	durumw heat	Monocot	*Triticumturgidum*	7.2	.	29.6	0.323	.	leaf	0.8236	.	.	Cieslinkietal.1996
Cd	Canada	ReginaSceptre	lab	7w eek	durumw heat	Monocot	*Triticumturgidum*	7.2	.	29.6	0.323	.	leaf	0.6844	.	.	Cieslinkietal.1996
Cd	Canada	WaitvilleDT623	lab	7w eek	durumw heat	Monocot	*Triticumturgidum*	6.2	.	12.2	0.124	.	leaf	0.0065	.	.	Cieslinkietal.1996
Cd	Canada	WaitvilleDT627	lab	7w eek	durumw heat	Monocot	*Triticumturgidum*	6.2	.	12.2	0.124	.	leaf	0.2443	.	.	Cieslinkietal.1996
Cd	Canada	WaitvilleKyle	lab	7w eek	durumw heat	Monocot	*Triticumturgidum*	6.2	.	12.2	0.124	.	leaf	0.402	.	.	Cieslinkietal.1996
Cd	Canada	WaitvilleSceptre	lab	7w eek	durumw heat	Monocot	*Triticumturgidum*	6.2	.	12.2	0.124	.	leaf	0.6132	.	.	Cieslinkietal.1996
Cd	Canada	ReginaACEmerson	lab	7w eek	flax	Dicot	*Linumusitatissimum*	7.2	.	29.6	0.323	.	leaf	1.402	.	.	Cieslinkietal.1996
Cd	Canada	ReginaFlanders	lab	7w eek	flax	Dicot	*Linumusitatissimum*	7.2	.	29.6	0.323	.	leaf	1.39	.	.	Cieslinkietal.1996
Cd	Canada	ReginaYSED	lab	7w eek	flax	Dicot	*Linumusitatissimum*	7.2	.	29.6	0.323	.	leaf	2.011	.	.	Cieslinkietal.1996
Cd	Canada	WaitvilleACEmerson	lab	7w eek	flax	Dicot	*Linumusitatissimum*	6.2	.	12.2	0.124	.	leaf	0.81	.	.	Cieslinkietal.1996
Cd	Canada	WaitvilleFlanders	lab	7w eek	flax	Dicot	*Linumusitatissimum*	6.2	.	12.2	0.124	.	leaf	0.5697	.	.	Cieslinkietal.1996
Cd	Canada	WaitvilleYSED2	lab	7w eek	flax	Dicot	*Linumusitatissimum*	6.2	.	12.2	0.124	.	leaf	0.476	.	.	Cieslinkietal.1996
Cd	Canada	Regina623	lab	7w eek	durumw heat	Monocot	*Triticumturgidum*	7.2	.	29.6	0.323	.	seed	0.0555	.	.	Cieslinkietal.1996

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
Cd	Canada	ReginaDT627	lab	7week	durumwheat	Monocot	*Triticumturgidum*	7.2	.	29.6	0.323	.	seed	0.0565	.	.	Cieslinkietal.1996
Cd	Canada	ReginaKyle	lab	7week	durumwheat	Monocot	*Triticumturgidum*	7.2	.	29.6	0.323	.	seed	0.0434	.	.	Cieslinkietal.1996
Cd	Canada	ReginaSceptre	lab	7week	durumwheat	Monocot	*Triticumturgidum*	7.2	.	29.6	0.323	.	seed	0.0557	.	.	Cieslinkietal.1996
Cd	Canada	WaitvilleDT623	lab	7week	durumwheat	Monocot	*Triticumturgidum*	6.2	.	12.2	0.124	.	seed	.	U	.	Cieslinkietal.1996
Cd	Canada	WaitvilleDT627	lab	7week	durumwheat	Monocot	*Triticumturgidum*	6.2	.	12.2	0.124	.	seed	0.0279	.	.	Cieslinkietal.1996
Cd	Canada	WaitvilleKyle	lab	7week	durumwheat	Monocot	*Triticumturgidum*	6.2	.	12.2	0.124	.	seed	0.0162	.	.	Cieslinkietal.1996
Cd	Canada	WaitvilleSceptre	lab	7week	durumwheat	Monocot	*Triticumturgidum*	6.2	.	12.2	0.124	.	seed	0.0229	.	.	Cieslinkietal.1996
Cd	Canada	Regina623	lab	maturity	durumwheat	Monocot	*Triticumturgidum*	7.2	.	29.6	0.323	.	seed	0.00259	.	.	Cieslinkietal.1996
Cd	Canada	ReginaDT627	lab	maturity	durumwheat	Monocot	*Triticumturgidum*	7.2	.	29.6	0.323	.	seed	0.0945	.	.	Cieslinkietal.1996
Cd	Canada	ReginaKyle	lab	maturity	durumwheat	Monocot	*Triticumturgidum*	7.2	.	29.6	0.323	.	seed	0.4988	.	.	Cieslinkietal.1996
Cd	Canada	ReginaSceptre	lab	maturity	durumwheat	Monocot	*Triticumturgidum*	7.2	.	29.6	0.323	.	seed	0.2907	.	.	Cieslinkietal.1996
Cd	Canada	WaitvilleDT623	lab	maturity	durumwheat	Monocot	*Triticumturgidum*	6.2	.	12.2	0.124	.	seed	0.0017	.	.	Cieslinkietal.1996
Cd	Canada	WaitvilleDT627	lab	maturity	durumwheat	Monocot	*Triticumturgidum*	6.2	.	12.2	0.124	.	seed	0.0085	.	.	Cieslinkietal.1996
Cd	Canada	WaitvilleKyle	lab	maturity	durumwheat	Monocot	*Triticumturgidum*	6.2	.	12.2	0.124	.	seed	0.0376	.	.	Cieslinkietal.1996
Cd	Canada	WaitvilleSceptre	lab	maturity	durumwheat	Monocot	*Triticumturgidum*	6.2	.	12.2	0.124	.	seed	0.0518	.	.	Cieslinkietal.1996
Cd	Canada	ReginaACEmerson	lab	maturity	flax	Dicot	*Linumusitatissimum*	7.2	.	29.6	0.323	.	seed	0.7831	.	.	Cieslinkietal.1996
Cd	Canada	ReginaFlanders	lab	maturity	flax	Dicot	*Linumusitatissimum*	7.2	.	29.6	0.323	.	seed	0.5348	.	.	Cieslinkietal.1996
Cd	Canada	ReginaYSED	lab	maturity	flax	Dicot	*Linumusitatissimum*	7.2	.	29.6	0.323	.	seed	1.0927	.	.	Cieslinkietal.1996
Cd	Canada	WaitvilleACEmerson	lab	maturity	flax	Dicot	*Linumusitatissimum*	6.2	.	12.2	0.124	.	seed	0.2683	.	.	Cieslinkietal.1996
Cd	Canada	WaitvilleFlanders	lab	maturity	flax	Dicot	*Linumusitatissimum*	6.2	.	12.2	0.124	.	seed	0.1999	.	.	Cieslinkietal.1996
Cd	Canada	WaitvilleYSED2	lab	maturity	flax	Dicot	*Linumusitatissimum*	6.2	.	12.2	0.124	.	seed	0.1217	.	.	Cieslinkietal.1996
Cd	Canada	Regina623	lab	maturity	durumwheat	Monocot	*Triticumturgidum*	7.2	.	29.6	0.323	.	stem	0.1943	.	.	Cieslinkietal.1996
Cd	Canada	ReginaDT627	lab	maturity	durumwheat	Monocot	*Triticumturgidum*	7.2	.	29.6	0.323	.	stem	0.247	.	.	Cieslinkietal.1996
Cd	Canada	ReginaKyle	lab	maturity	durumwheat	Monocot	*Triticumturgidum*	7.2	.	29.6	0.323	.	stem	0.6512	.	.	Cieslinkietal.1996
Cd	Canada	ReginaSceptre	lab	maturity	durumwheat	Monocot	*Triticumturgidum*	7.2	.	29.6	0.323	.	stem	0.2574	.	.	Cieslinkietal.1996
Cd	Canada	WaitvilleDT623	lab	maturity	durumwheat	Monocot	*Triticumturgidum*	6.2	.	12.2	0.124	.	stem	0.0409	.	.	Cieslinkietal.1996
Cd	Canada	WaitvilleDT627	lab	maturity	durumwheat	Monocot	*Triticumturgidum*	6.2	.	12.2	0.124	.	stem	0.0557	.	.	Cieslinkietal.1996
Cd	Canada	WaitvilleKyle	lab	maturity	durumwheat	Monocot	*Triticumturgidum*	6.2	.	12.2	0.124	.	stem	0.1778	.	.	Cieslinkietal.1996
Cd	Canada	WaitvilleSceptre	lab	maturity	durumwheat	Monocot	*Triticumturgidum*	6.2	.	12.2	0.124	.	stem	0.0933	.	.	Cieslinkietal.1996
Cd	Canada	ReginaACEmerson	lab	maturity	flax	Dicot	*Linumusitatissimum*	7.2	.	29.6	0.323	.	stem	0.6695	.	.	Cieslinkietal.1996
Cd	Canada	ReginaFlanders	lab	maturity	flax	Dicot	*Linumusitatissimum*	7.2	.	29.6	0.323	.	stem	0.8257	.	.	Cieslinkietal.1996
Cd	Canada	ReginaYSED	lab	maturity	flax	Dicot	*Linumusitatissimum*	7.2	.	29.6	0.323	.	stem	1.3032	.	.	Cieslinkietal.1996
Cd	Canada	WaitvilleACEmerson	lab	maturity	flax	Dicot	*Linumusitatissimum*	6.2	.	12.2	0.124	.	stem	0.2729	.	.	Cieslinkietal.1996
Cd	Canada	WaitvilleFlanders	lab	maturity	flax	Dicot	*Linumusitatissimum*	6.2	.	12.2	0.124	.	stem	0.4944	.	.	Cieslinkietal.1996
Cd	Canada	WaitvilleYSED2	lab	maturity	flax	Dicot	*Linumusitatissimum*	6.2	.	12.2	0.124	.	stem	0.4893	.	.	Cieslinkietal.1996
Cd	India	Polluted	field	resident	Rice	Monocot	*Oryzasativa*	.	.	.	2.6	.	leaf	1.8	.	.	Fazelietal.1998
Cd	India	Unpolluted	field	resident	Rice	Monocot	*Oryzasativa*	.	.	.	0.9	.	leaf	0.8	.	.	Fazelietal.1998
Cd	India	Polluted	field	resident	Rice	Monocot	*Oryzasativa*	.	.	.	2.6	.	seed	0.2	.	.	Fazelietal.1998
Cd	India	Unpolluted	field	resident	Rice	Monocot	*Oryzasativa*	.	.	.	0.9	.	seed	0.1	.	.	Fazelietal.1998
Cd	Spain	1)Roadsideedge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.8	7	18	1.72	.	wholeplant	0.464	.	.	Garciaetal.1996
Cd	Spain	2)Roadsideedge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.4	9.5	29	0.17	.	wholeplant	0.059	.	.	Garciaetal.1996
Cd	Spain	3)Roadsideedge	field	resident	Ryegrass	Monocot	*Loliumperenne*	8.1	4.2	15	0.9	.	wholeplant	0.026	.	.	Garciaetal.1996
Cd	Spain	4)Roadsideedge	field	resident	Ryegrass	Monocot	*Loliumperenne*	8	2.7	18	0.16	.	wholeplant	0.027	.	.	Garciaetal.1996
Cd	Spain	5)Roadsideedge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.6	10.6	27	0.4	.	wholeplant	0.027	.	.	Garciaetal.1996
Cd	Spain	6)Roadsideedge	field	resident	Ryegrass	Monocot	*Loliumperenne*	8.2	4.5	16	0.8	.	wholeplant	0.096	.	.	Garciaetal.1996
Cd	Spain	7)Roadsideedge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.9	7.4	19	1.34	.	wholeplant	0.108	.	.	Garciaetal.1996
Cd	Spain	8)Roadsideedge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.8	5	16	0.34	.	wholeplant	0.03	.	.	Garciaetal.1996
Cd	Spain	1)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.6	6.2	36	0.22	.	wholeplant	0.029	.	.	Garciaetal.1996
Cd	Spain	2)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	*Loliumperenne*	5.7	6.4	34	0.02	.	wholeplant	0.065	.	.	Garciaetal.1996
Cd	Spain	3)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7	10.6	48	0.24	.	wholeplant	0.051	.	.	Garciaetal.1996
Cd	Spain	4)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.7	3.1	27	0.14	.	wholeplant	0.029	.	.	Garciaetal.1996
Cd	Spain	5)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	*Loliumperenne*	6.9	24.6	51	0.41	.	wholeplant	0.031	.	.	Garciaetal.1996
Cd	Spain	6)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	*Loliumperenne*	6.9	6.4	30	0.32	.	wholeplant	0.051	.	.	Garciaetal.1996
Cd	Spain	7)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.7	8.5	26	0.78	.	wholeplant	0.073	.	.	Garciaetal.1996

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
Cd	Spain	8)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.9	5.2	24	0.24	.	w holeplant	0.01	.	.	Garciaetal.1996
Cd	Netherlands	Bath	field	resident	saltmarshhalophyte	Dicot	*Astertripolium*	.	.	.	3.095	.	w holeplant	4.24	.	.	Hemmingaetal.1989
Cd	Netherlands	Ellew outsdijk	field	resident	saltmarshhalophyte	Dicot	*Astertripolium*	.	.	.	0.69	.	w holeplant	1.2	.	.	Hemmingaetal.1989
Cd	Netherlands	Waarde	field	resident	saltmarshhalophyte	Dicot	*Astertripolium*	.	.	.	1.595	.	w holeplant	5.4	.	.	Hemmingaetal.1989
Cd	Korea	miningsite	field	resident	Corn	Monocot	*Zeamays*	5.75	.	5.2	11.8	.	seed	0.26	.	8	JungandThornton1996
Cd	Korea	after30days	field	resident	Rice	Monocot	*Oryzasativa*	5.5	.	13.2	1.3	.	leaf/stem	0.35	.	14	JungandThornton1997
Cd	Korea	after80days	field	resident	Rice	Monocot	*Oryzasativa*	5.5	.	11.3	1.3	.	leaf/stem	0.46	.	31	JungandThornton1997
Cd	Korea	after150days	field	resident	Rice	Monocot	*Oryzasativa*	5.3	.	11.3	1.6	.	seed	0.77	.	.	JungandThornton1997
Cd	Reisenberg	3mg/kg	lab	40day	sunflow er	Dicot	*Helianthusannuus*	7.7	4.9	21.0	2	.	leaf	2.05	.	.	Lombietal.1998
Cd	Untertiefenbach	3mg/kg	lab	40day	sunflow er	Dicot	*Helianthusannuus*	7.5	6.0	27.1	1.67	.	leaf	0.93	.	.	Lombietal.1998
Cd	Weyersdorf	3mg/kg	lab	40day	sunflow er	Dicot	*Helianthusannuus*	6.9	3.5	10.9	1.83	.	leaf	3.21	.	.	Lombietal.1998
Cd	Reisenberg	6mg/kg	lab	40day	sunflow er	Dicot	*Helianthusannuus*	7.7	4.9	21.0	4.17	.	leaf	3.65	.	.	Lombietal.1998
Cd	Untertiefenbach	6mg/kg	lab	40day	sunflow er	Dicot	*Helianthusannuus*	7.5	6.0	27.1	3.20	.	leaf	2.31	.	.	Lombietal.1998
Cd	Weyersdorf	6mg/kg	lab	40day	sunflow er	Dicot	*Helianthusannuus*	6.9	3.5	10.9	3.57	.	leaf	14.2	.	.	Lombietal.1998
Cd	Reisenberg	9mg/kg	lab	40day	sunflow er	Dicot	*Helianthusannuus*	7.7	4.9	21.0	5.60	.	leaf	4.7	.	.	Lombietal.1998
Cd	Untertiefenbach	9mg/kg	lab	40day	sunflow er	Dicot	*Helianthusannuus*	7.5	6.0	27.1	5.20	.	leaf	7.39	.	.	Lombietal.1998
Cd	Reisenberg	Control	lab	40day	sunflow er	Dicot	*Helianthusannuus*	7.7	4.9	21.0	0.35	.	leaf	0.29	.	.	Lombietal.1998
Cd	Weyersdorf	Control	lab	40day	sunflow er	Dicot	*Helianthusannuus*	6.9	3.5	10.9	0.22	.	leaf	0.32	.	.	Lombietal.1998
Cd	Untertiefenbach	Control	lab	40day	sunflow er	Dicot	*Helianthusannuus*	7.5	6.0	27.1	0.29	.	leaf	0.33	.	.	Lombietal.1998
Cd	Reisenberg	3mg/kg	lab	40day	sunflow er	Dicot	*Helianthusannuus*	7.7	4.9	21.0	2	.	seed	0.67	.	.	Lombietal.1998
Cd	Untertiefenbach	3mg/kg	lab	40day	sunflow er	Dicot	*Helianthusannuus*	7.5	6.0	27.1	1.67	.	seed	0.57	.	.	Lombietal.1998
Cd	Weyersdorf	3mg/kg	lab	40day	sunflow er	Dicot	*Helianthusannuus*	6.9	3.5	10.9	1.83	.	seed	1.00	.	.	Lombietal.1998
Cd	Reisenberg	6mg/kg	lab	40day	sunflow er	Dicot	*Helianthusannuus*	7.7	4.9	21.0	4.17	.	seed	1.72	.	.	Lombietal.1998
Cd	Untertiefenbach	6mg/kg	lab	40day	sunflow er	Dicot	*Helianthusannuus*	7.5	6.0	27.1	3.20	.	seed	1.64	.	.	Lombietal.1998
Cd	Weyersdorf	6mg/kg	lab	40day	sunflow er	Dicot	*Helianthusannuus*	6.9	3.5	10.9	3.57	.	seed	1.67	.	.	Lombietal.1998
Cd	Reisenberg	9mg/kg	lab	40day	sunflow er	Dicot	*Helianthusannuus*	7.7	4.9	21.0	5.60	.	seed	0.68	.	.	Lombietal.1998
Cd	Untertiefenbach	9mg/kg	lab	40day	sunflow er	Dicot	*Helianthusannuus*	7.5	6.0	27.1	5.20	.	seed	2.64	.	.	Lombietal.1998
Cd	Reisenberg	Control	lab	40day	sunflow er	Dicot	*Helianthusannuus*	7.7	4.9	21.0	0.35	.	seed	0.40	.	.	Lombietal.1998
Cd	Weyersdorf	Control	lab	40day	sunflow er	Dicot	*Helianthusannuus*	6.9	3.5	10.9	0.22	.	seed	0.13	.	.	Lombietal.1998
Cd	Untertiefenbach	Control	lab	40day	sunflow er	Dicot	*Helianthusannuus*	7.5	6.0	27.1	0.29	.	seed	0.19	.	.	Lombietal.1998
Cd	Montana	milltow n(reference)	field	resident	Grass	Monocot	.	.	.	.	1.9	.	leaf	0.6	.	1	Pascoeetal.1996
Cd	Montana	milltow n(reference)	field	resident	forb	Dicot	.	.	.	.	1.9	.	leaf/stem	0.21	.	2	Pascoeetal.1996
Cd	Montana	milltow n	field	resident	Grass	Monocot	.	.	.	.	7.3	.	leaf	0.9	.	4	Pascoeetal.1996
Cd	Montana	milltow n	field	resident	forb	Dicot	.	.	.	.	7.3	.	leaf/stem	2.8	.	20	Pascoeetal.1996
Cd	Germany	Br	field	resident	greenalgae	Chlorophyta	.	.	.	.	3.37	.	w holeplant	1.21	.	.	Posthuma1990
Cd	Netherlands	Bu	field	resident	greenalgae	Chlorophyta	.	.	.	.	5.03	.	w holeplant	3.8	.	.	Posthuma1990
Cd	Netherlands	Mo	field	resident	greenalgae	Chlorophyta	.	.	.	.	1.12	.	w holeplant	1.03	.	.	Posthuma1990
Cd	Belgium	Pl	field	resident	greenalgae	Chlorophyta	.	.	.	.	27.5	.	w holeplant	2.9	.	.	Posthuma1990
Cd	Germany	St	field	resident	greenalgae	Chlorophyta	.	.	.	.	62.6	.	w holeplant	5.3	.	.	Posthuma1990
Cd	Oklahoma	GRID3	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.6	.	30.7	25.2	.	seed	28.1	J	.	PTI1995
Cd	Oklahoma	GRID4	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	5.95	.	20.95	33.1	.	seed	8.1	.	.	PTI1995
Cd	Oklahoma	TRAP1	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.4	.	14.1	144	.	seed	144	.	.	PTI1995
Cd	Oklahoma	TRAP2	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6	.	31.7	36	.	seed	36	.	.	PTI1995
Cd	Oklahoma	TRAP2	field	resident	Greenbriar	Monocot	*Smilaxbona-nox*	6	.	31.7	36	.	seed	36	.	.	PTI1995
Cd	Oklahoma	GRID2	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.1	.	36.3	69.8	.	seed	0.2	J	.	PTI1995
Cd	Oklahoma	GRID3	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.6	.	30.7	25.2	.	seed	0.24	J	.	PTI1995
Cd	Oklahoma	TERA	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7	.	32.6	1.295	.	seed	1.295	.	.	PTI1995
Cd	Oklahoma	TERB	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.5	.	20.3	3.45	.	seed	3.45	.	.	PTI1995
Cd	Oklahoma	TERC	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.8	.	18.8	0.77	.	seed	0.77	J	.	PTI1995
Cd	Oklahoma	GRID1	field	resident	Millet	Monocot	*Panicumvirgatum*	7.1	.	21.6	26.6	.	seed	1.7	.	.	PTI1995
Cd	Oklahoma	GRID2	field	resident	Millet	Monocot	*Panicumvirgatum*	6.1	.	36.3	69.8	.	seed	0.6	J	.	PTI1995
Cd	Oklahoma	GRID4	field	resident	Millet	Monocot	*Panicumvirgatum*	5.95	.	20.95	33.1	.	seed	0.24	.	.	PTI1995
Cd	Oklahoma	TERA	field	resident	Millet	Monocot	*Panicumvirgatum*	7	.	32.6	1.295	.	seed	1.295	.	.	PTI1995
Cd	Oklahoma	TERB	field	resident	Millet	Monocot	*Panicumvirgatum*	6.5	.	20.3	3.45	.	seed	3.45	.	.	PTI1995

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
Cd	Oklahoma	GRID2	field	resident	Pigw eed	Dicot	*Amaranthuspalmeri*	6.1	.	36.3	69.8	.	seed	32.8	J	.	PTI1995
Cd	Oklahoma	GRID1	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	7.1	.	21.6	26.6	.	seed	4.4	.	.	PTI1995
Cd	Oklahoma	GRID3	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	6.6	.	30.7	25.2	.	seed	15.4	J	.	PTI1995
Cd	Oklahoma	GRID4	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	5.95	.	20.95	33.1	.	seed	12.9	.	.	PTI1995
Cd	Oklahoma	TERA	field	resident	Ragw eed	Dicot	*Ambrosiapsilostachya*	7	.	32.6	1.295	.	seed	1.295	.	.	PTI1995
Cd	Oklahoma	TERB	field	resident	Ragw eed	Dicot	*Ambrosiapsilostachya*	6.5	.	20.3	3.45	.	seed	3.45	.	.	PTI1995
Cd	Oklahoma	TERC	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	6.8	.	18.8	0.77	.	seed	0.77	J	.	PTI1995
Cd	Oklahoma	TRAP1	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	6.4	.	14.1	144	.	seed	144	.	.	PTI1995
Cd	Oklahoma	TRAP1	field	resident	Ragw eed	Dicot	*Ambrosiatrifida*	6.4	.	14.1	144	.	seed	144	.	.	PTI1995
Cd	Oklahoma	TRAP2	field	resident	Ragw eed	Dicot	*Ambrosiatrifida*	6	.	31.7	36	.	seed	36	.	.	PTI1995
Cd	Wyoming	Reference	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	0.21	.	leaf	0.18	.	.	RamirezandRogers2000
Cd	Wyoming	Reference	field	resident	Brome	Monocot	*Bromussp.*	.	.	.	0.21	.	leaf	0.11	.	.	RamirezandRogers2000
Cd	Wyoming	StudyArea	field	resident	Brome	Monocot	*Bromussp.*	.	.	.	0.09	.	leaf	0.03	.	.	RamirezandRogers2000
Cd	Wyoming	StudyArea	field	resident	Dandelion	Dicot	*Taraxacumofficinale*	.	.	.	0.09	.	leaf	0.34	.	.	RamirezandRogers2000
Cd	Wyoming	StudyArea	field	resident	FoxtailBarley	Dicot	*Hordiumjubatum*	.	.	.	0.09	.	leaf	0.01	.	.	RamirezandRogers2000
Cd	Wyoming	Reference	field	resident	KentuckyBluegrass	Monocot	*PoaPratensis*	.	.	.	0.21	.	leaf	0.09	.	.	RamirezandRogers2000
Cd	Wyoming	StudyArea	field	resident	Pondw eed	Monocot	*Potamogetonsp*	.	.	.	0.00	.	leaf	0.10	.	.	RamirezandRogers2000
chrysene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.0037	.	leaf/stem	0.0006	.	.	Kipopoulouetal.1999
chrysene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0037	.	leaf/stem	.	.	.	Kipopoulouetal.1999
chrysene	.	.	.	.	endive	.	.	.	.	.	0.0037	.	leaf/stem	0.0039	.	.	Kipopoulouetal.1999
chrysene	.	.	.	.	leek	.	.	.	.	.	0.0037	.	leaf/stem	0.0019	.	.	Kipopoulouetal.1999
chrysene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.0037	.	leaf/stem	0.0039	.	.	Kipopoulouetal.1999
chrysene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.0037	.	root	.	.	.	Kipopoulouetal.1999
chrysene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0037	.	root	0.00048	.	.	Kipopoulouetal.1999
chrysene	.	.	.	.	endive	.	.	.	.	.	0.0037	.	root	.	.	.	Kipopoulouetal.1999
chrysene	.	.	.	.	leek	.	.	.	.	.	0.0037	.	root	.	.	.	Kipopoulouetal.1999
chrysene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.0037	.	root	.	.	.	Kipopoulouetal.1999
Co	India	Polluted	field	resident	Rice	Monocot	*Oryzasativa*	.	.	.	38	.	leaf	21	.	.	Fazelietal.1998
Co	India	Unpolluted	field	resident	Rice	Monocot	*Oryzasativa*	.	.	.	21	.	leaf	11	.	.	Fazelietal.1998
Co	India	Polluted	field	resident	Rice	Monocot	*Oryzasativa*	.	.	.	38	.	seed	8	.	.	Fazelietal.1998
Co	India	Unpolluted	field	resident	Rice	Monocot	*Oryzasativa*	.	.	.	21	.	seed	2	.	.	Fazelietal.1998
Co	Oklahoma	GRID3	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.6	.	30.7	8.3	.	seed	0.16	J	.	PTI1995
Co	Oklahoma	GRID4	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	5.95	.	20.95	10.15	.	seed	0.09	.	.	PTI1995
Co	Oklahoma	TRAP1	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.4	.	14.1	14.9	.	seed	14.9	.	.	PTI1995
Co	Oklahoma	TRAP2	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6	.	31.7	9.6	.	seed	9.6	.	.	PTI1995
Co	Oklahoma	TRAP2	field	resident	Greenbriar	Monocot	*Smilaxbona-nox*	6	.	31.7	9.6	.	seed	9.6	.	.	PTI1995
Co	Oklahoma	GRID1	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7.1	.	21.6	15.6	.	seed	0.05	.	.	PTI1995
Co	Oklahoma	GRID2	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.1	.	36.3	9.2	.	seed	0.03	J	.	PTI1995
Co	Oklahoma	GRID3	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.6	.	30.7	8.3	.	seed	0.03	J	.	PTI1995
Co	Oklahoma	TERA	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7	.	32.6	7.55	.	seed	7.55	.	.	PTI1995
Co	Oklahoma	TERB	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.5	.	20.3	8.35	.	seed	8.35	.	.	PTI1995
Co	Oklahoma	TERC	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.8	.	18.8	13.95	.	seed	13.95	J	.	PTI1995
Co	Oklahoma	GRID1	field	resident	Millet	Monocot	*Panicumvirgatum*	7.1	.	21.6	15.6	.	seed	0.25	.	.	PTI1995
Co	Oklahoma	GRID2	field	resident	Millet	Monocot	*Panicumvirgatum*	6.1	.	36.3	9.2	.	seed	0.09	J	.	PTI1995
Co	Oklahoma	GRID4	field	resident	Millet	Monocot	*Panicumvirgatum*	5.95	.	20.95	10.15	.	seed	0.03	.	.	PTI1995
Co	Oklahoma	TERA	field	resident	Millet	Monocot	*Panicumvirgatum*	7	.	32.6	7.55	.	seed	7.55	.	.	PTI1995
Co	Oklahoma	TERB	field	resident	Millet	Monocot	*Panicumvirgatum*	6.5	.	20.3	8.35	.	seed	8.35	.	.	PTI1995
Co	Oklahoma	TERC	field	resident	Millet	Monocot	*Panicumvirgatum*	6.8	.	18.8	13.95	.	seed	13.95	J	.	PTI1995
Co	Oklahoma	GRID2	field	resident	Pigw eed	Dicot	*Amaranthuspalmeri*	6.1	.	36.3	9.2	.	seed	0.12	J	.	PTI1995
Co	Oklahoma	GRID1	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	7.1	.	21.6	15.6	.	seed	0.15	.	.	PTI1995
Co	Oklahoma	GRID3	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	6.6	.	30.7	8.3	.	seed	0.11	J	.	PTI1995
Co	Oklahoma	GRID4	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	5.95	.	20.95	10.15	.	seed	0.09	.	.	PTI1995
Co	Oklahoma	TERA	field	resident	Ragw eed	Dicot	*Ambrosiapsilostachya*	7	.	32.6	7.55	.	seed	7.55	.	.	PTI1995
Co	Oklahoma	TERB	field	resident	Ragw eed	Dicot	*Ambrosiapsilostachya*	6.5	.	20.3	8.35	.	seed	8.35	.	.	PTI1995

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
Co	Oklahoma	TERC	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.8	.	18.8	13.95	.	seed	13.95	J	.	PTI1995
Co	Oklahoma	TRAP1	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.4	.	14.1	14.9	.	seed	14.9	.	.	PTI1995
Co	Oklahoma	TRAP1	field	resident	Ragweed	Dicot	*Ambrosiatrifida*	6.4	.	14.1	14.9	.	seed	14.9	.	.	PTI1995
Co	Oklahoma	TRAP2	field	resident	Ragweed	Dicot	*Ambrosiatrifida*	6	.	31.7	9.6	.	seed	9.6	.	.	PTI1995
Co	Canada	.	field	resident	Blueberry	Dicot	*Vacciniumangustifolium*	.	.	.	11	.	leaf	0.2	U	.	SheppardandEvenden1990
Coronene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.003904	.	leaf/stem	0.018	.	.	WildandJones1992
Coronene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.011904	.	leaf/stem	0.007	.	.	WildandJones1992
Coronene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.039744	.	leaf/stem	0.023	.	.	WildandJones1992
Coronene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.003904	.	root	0.0005	.	.	WildandJones1992
Coronene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.011904	.	root	0.0009	.	.	WildandJones1992
Coronene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.039744	.	root	0	.	.	WildandJones1992
Cr	India	Polluted	field	resident	Rice	Monocot	*Oryzasativa*	.	.	.	320	.	leaf	29	.	.	Fazelietal.1998
Cr	India	Unpolluted	field	resident	Rice	Monocot	*Oryzasativa*	.	.	.	134	.	leaf	16	.	.	Fazelietal.1998
Cr	India	Polluted	field	resident	Rice	Monocot	*Oryzasativa*	.	.	.	320	.	seed	14	.	.	Fazelietal.1998
Cr	India	Unpolluted	field	resident	Rice	Monocot	*Oryzasativa*	.	.	.	134	.	seed	9	.	.	Fazelietal.1998
Cr	Oklahoma	GRID3	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.6	.	30.7	21.4	.	seed	4.2	J	.	PTI1995
Cr	Oklahoma	GRID4	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	5.95	.	20.95	26.45	.	seed	7.8	.	.	PTI1995
Cr	Oklahoma	TRAP1	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.4	.	14.1	42.9	.	seed	42.9	.	.	PTI1995
Cr	Oklahoma	TRAP2	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6	.	31.7	25.2	.	seed	25.2	.	.	PTI1995
Cr	Oklahoma	TRAP2	field	resident	Greenbriar	Monocot	*Smilaxbona-nox*	6	.	31.7	25.2	.	seed	25.2	.	.	PTI1995
Cr	Oklahoma	GRID1	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7.1	.	21.6	27.3	.	seed	3.1	.	.	PTI1995
Cr	Oklahoma	GRID2	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.1	.	36.3	24.7	.	seed	2	J	.	PTI1995
Cr	Oklahoma	GRID3	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.6	.	30.7	21.4	.	seed	1.5	J	.	PTI1995
Cr	Oklahoma	TERA	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7	.	32.6	23.6	.	seed	23.6	.	.	PTI1995
Cr	Oklahoma	TERB	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.5	.	20.3	32.8	.	seed	32.8	.	.	PTI1995
Cr	Oklahoma	TERC	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.8	.	18.8	37.3	.	seed	37.3	J	.	PTI1995
Cr	Oklahoma	GRID1	field	resident	Millet	Monocot	*Panicumvirgatum*	7.1	.	21.6	27.3	.	seed	2	.	.	PTI1995
Cr	Oklahoma	GRID2	field	resident	Millet	Monocot	*Panicumvirgatum*	6.1	.	36.3	24.7	.	seed	1.1	J	.	PTI1995
Cr	Oklahoma	GRID4	field	resident	Millet	Monocot	*Panicumvirgatum*	5.95	.	20.95	26.45	.	seed	0.7	.	.	PTI1995
Cr	Oklahoma	TERA	field	resident	Millet	Monocot	*Panicumvirgatum*	7	.	32.6	23.6	.	seed	23.6	.	.	PTI1995
Cr	Oklahoma	TERB	field	resident	Millet	Monocot	*Panicumvirgatum*	6.5	.	20.3	32.8	.	seed	32.8	.	.	PTI1995
Cr	Oklahoma	TERC	field	resident	Millet	Monocot	*Panicumvirgatum*	6.8	.	18.8	37.3	.	seed	37.3	J	.	PTI1995
Cr	Oklahoma	GRID2	field	resident	Pigweed	Dicot	*Amaranthuspalmeri*	6.1	.	36.3	24.7	.	seed	1.4	J	.	PTI1995
Cr	Oklahoma	GRID1	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	7.1	.	21.6	27.3	.	seed	0.9	.	.	PTI1995
Cr	Oklahoma	GRID3	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.6	.	30.7	21.4	.	seed	0.7	J	.	PTI1995
Cr	Oklahoma	GRID4	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	5.95	.	20.95	26.45	.	seed	1.8	.	.	PTI1995
Cr	Oklahoma	TERA	field	resident	Ragweed	Dicot	*Ambrosiapsilostachya*	7	.	32.6	23.6	.	seed	23.6	.	.	PTI1995
Cr	Oklahoma	TERB	field	resident	Ragweed	Dicot	*Ambrosiapsilostachya*	6.5	.	20.3	32.8	.	seed	32.8	.	.	PTI1995
Cr	Oklahoma	TERC	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.8	.	18.8	37.3	.	seed	37.3	J	.	PTI1995
Cr	Oklahoma	TRAP1	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.4	.	14.1	42.9	.	seed	42.9	.	.	PTI1995
Cr	Oklahoma	TRAP1	field	resident	Ragweed	Dicot	*Ambrosiatrifida*	6.4	.	14.1	42.9	.	seed	42.9	.	.	PTI1995
Cr	Oklahoma	TRAP2	field	resident	Ragweed	Dicot	*Ambrosiatrifida*	6	.	31.7	25.2	.	seed	25.2	.	.	PTI1995
Cu	California	Kesterson	field	resident	BirdfootTrefoil	Dicot	*Lotuscorniculatus*	.	.	.	22	.	leaf/stem	5.3	.	.	Banuelosetal.1999
Cu	California	Kesterson	field	resident	Mustard	Dicot	*Brassicajuncea*	.	.	.	22	.	leaf/stem	5.2	.	.	Banuelosetal.1999
Cu	California	Kesterson	field	resident	Rose-Mallow	Dicot	*Hibiscuscanabinus*	.	.	.	22	.	leaf/stem	11	.	.	Banuelosetal.1999
Cu	California	Kesterson	field	resident	TallFescue	Monocot	*Festucaarundinacea*	.	.	.	22	.	leaf/stem	1.1	.	.	Banuelosetal.1999
Cu	California	Kesterson	field	resident	BirdfootTrefoil	Dicot	*Lotuscorniculatus*	.	.	.	22	.	root	5.1	.	.	Banuelosetal.1999
Cu	California	Kesterson	field	resident	Mustard	Dicot	*Brassicajuncea*	.	.	.	22	.	root	4.3	.	.	Banuelosetal.1999
Cu	California	Kesterson	field	resident	Rose-Mallow	Dicot	*Hibiscuscanabinus*	.	.	.	22	.	root	6.2	.	.	Banuelosetal.1999
Cu	California	Kesterson	field	resident	TallFescue	Monocot	*Festucaarundinacea*	.	.	.	22	.	root	5.2	.	.	Banuelosetal.1999
Cu	Pennsylvania	Palmerton	field	resident	acorns/berries	Dicot	mixedfruitsandacorns	5.9	12	14	9.9	.	fruit/seed	6.2	.	3	Beyeretal.1985
Cu	Pennsylvania	BakeOvenKnob	field	resident	acorns/berries	Dicot	mixedfruitsandacorns	5	23	19	18	.	fruit/seed	9.5	.	4	Beyeretal.1985
Cu	Maryland	1	field	resident	CommonReed	Monocot	*Phragmitesaustralis*	3	.	.	24	.	leaf	2.5	.	.	Beyeretal.1990
Cu	Delaware	2	field	resident	CommonReed	Monocot	*Phragmitesaustralis*	5.2	.	.	15	.	leaf	2.8	.	.	Beyeretal.1990

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
Cu	Maryland	3	field	resident	CommonReed	Monocot	*Phragmitesaustralis*	3.1	.	.	71	.	leaf	6.1	.	.	Beyeretal.1990
Cu	Pennsylvania	4	field	resident	CommonReed	Monocot	*Phragmitesaustralis*	6.3	.	.	130	.	leaf	3.9	.	.	Beyeretal.1990
Cu	Maryland	5	field	resident	CommonReed	Monocot	*Phragmitesaustralis*	3.6	.	.	150	.	leaf	4.7	.	.	Beyeretal.1990
Cu	India	Polluted	field	resident	Rice	Monocot	*Oryzasativa*	.	.	.	49	.	leaf	13	.	.	Fazelietal.1998
Cu	India	Unpolluted	field	resident	Rice	Monocot	*Oryzasativa*	.	.	.	32	.	leaf	9	.	.	Fazelietal.1998
Cu	India	Polluted	field	resident	Rice	Monocot	*Oryzasativa*	.	.	.	49	.	seed	25	.	.	Fazelietal.1998
Cu	India	Unpolluted	field	resident	Rice	Monocot	*Oryzasativa*	.	.	.	32	.	seed	18	.	.	Fazelietal.1998
Cu	Spain	1)Roadsideedge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.8	7	18	162	.	wholeplant	13.27	.	.	Garciaetal.1996
Cu	Spain	2)Roadsideedge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.4	9.5	29	10	.	wholeplant	9.32	.	.	Garciaetal.1996
Cu	Spain	3)Roadsideedge	field	resident	Ryegrass	Monocot	*Loliumperenne*	8.1	4.2	15	121	.	wholeplant	9.04	.	.	Garciaetal.1996
Cu	Spain	4)Roadsideedge	field	resident	Ryegrass	Monocot	*Loliumperenne*	8	2.7	18	23	.	wholeplant	7.4	.	.	Garciaetal.1996
Cu	Spain	5)Roadsideedge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.6	10.6	27	45	.	wholeplant	9.5	.	.	Garciaetal.1996
Cu	Spain	6)Roadsideedge	field	resident	Ryegrass	Monocot	*Loliumperenne*	8.2	4.5	16	77	.	wholeplant	11.33	.	.	Garciaetal.1996
Cu	Spain	7)Roadsideedge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.9	7.4	19	104	.	wholeplant	11.59	.	.	Garciaetal.1996
Cu	Spain	8)Roadsideedge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.8	5	16	86	.	wholeplant	7.94	.	.	Garciaetal.1996
Cu	Spain	1)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.6	6.2	36	34	.	wholeplant	7.61	.	.	Garciaetal.1996
Cu	Spain	2)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	*Loliumperenne*	5.7	6.4	34	10	.	wholeplant	8.7	.	.	Garciaetal.1996
Cu	Spain	3)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7	10.6	48	58	.	wholeplant	6.74	.	.	Garciaetal.1996
Cu	Spain	4)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.7	3.1	27	18	.	wholeplant	8.54	.	.	Garciaetal.1996
Cu	Spain	5)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	*Loliumperenne*	6.9	24.6	51	39	.	wholeplant	10.76	.	.	Garciaetal.1996
Cu	Spain	6)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	*Loliumperenne*	6.9	6.4	30	31	.	wholeplant	10.03	.	.	Garciaetal.1996
Cu	Spain	7)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.7	8.5	26	55	.	wholeplant	7.54	.	.	Garciaetal.1996
Cu	Spain	8)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.9	5.2	24	30	.	wholeplant	8.45	.	.	Garciaetal.1996
Cu	Netherlands	Bath	field	resident	saltmarshhalophyte	Dicot	*Astertripolium*	.	.	.	35.2	.	wholeplant	11.7	.	.	Hemmingaetal.1989
Cu	Netherlands	Ellew outsdijk	field	resident	saltmarshhalophyte	Dicot	*Astertripolium*	.	.	.	21.3	.	wholeplant	8.1	.	.	Hemmingaetal.1989
Cu	Netherlands	Waarde	field	resident	saltmarshhalophyte	Dicot	*Astertripolium*	.	.	.	27.8	.	wholeplant	3.7	.	.	Hemmingaetal.1989
Cu	Korea	miningsite	field	resident	Corn	Monocot	*Zeamays*	5.75	.	5.2	208	.	seed	2.7	.	8	JungandThornton1996
Cu	Korea	after30days	field	resident	Rice	Monocot	*Oryzasativa*	5.5	.	13.2	35	.	leaf/stem	10.4	.	14	JungandThornton1997
Cu	Korea	after80days	field	resident	Rice	Monocot	*Oryzasativa*	5.5	.	11.3	33	.	leaf/stem	9.5	.	31	JungandThornton1997
Cu	Korea	after150days	field	resident	Rice	Monocot	*Oryzasativa*	5.3	.	11.3	32	.	seed	9.7	.	.	JungandThornton1997
Cu	Reisenberg	100mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.7	4.9	21.0	90.3	.	leaf	12.5	.	.	Lombietal.1998
Cu	Untertiefenbach	100mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	78.33	.	leaf	14.73	.	.	Lombietal.1998
Cu	Weyersdorf	100mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	6.9	3.5	10.9	81.0	.	leaf	15.4	.	.	Lombietal.1998
Cu	Reisenberg	200mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.7	4.9	21.0	169.0	.	leaf	9.38	.	.	Lombietal.1998
Cu	Untertiefenbach	200mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	139.0	.	leaf	17.57	.	.	Lombietal.1998
Cu	Weyersdorf	200mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	6.9	3.5	10.9	145.7	.	leaf	16.2	.	.	Lombietal.1998
Cu	Reisenberg	300mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.7	4.9	21.0	217.3	.	leaf	11.4	.	.	Lombietal.1998
Cu	Untertiefenbach	300mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	208.6	.	leaf	14.97	.	.	Lombietal.1998
Cu	Reisenberg	Control	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.7	4.9	21.0	26.0	.	leaf	10.5	.	.	Lombietal.1998
Cu	Untertiefenbach	Control	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	17.67	.	leaf	6.77	.	.	Lombietal.1998
Cu	Weyersdorf	Control	lab	40day	sunflower	Dicot	*Helianthusannuus*	6.9	3.5	10.9	13.3	.	leaf	4.3	.	.	Lombietal.1998
Cu	Reisenberg	100mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.7	4.9	21.0	90.3	.	seed	17.3	.	.	Lombietal.1998
Cu	Untertiefenbach	100mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	78.33	.	seed	17.73	.	.	Lombietal.1998
Cu	Weyersdorf	100mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	6.9	3.5	10.9	81.0	.	seed	17.6	.	.	Lombietal.1998
Cu	Reisenberg	200mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.7	4.9	21.0	169.0	.	seed	19.5	.	.	Lombietal.1998
Cu	Untertiefenbach	200mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	139.0	.	seed	13.77	.	.	Lombietal.1998
Cu	Weyersdorf	200mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	6.9	3.5	10.9	145.7	.	seed	22.1	.	.	Lombietal.1998
Cu	Reisenberg	300mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.7	4.9	21.0	217.3	.	seed	16.0	.	.	Lombietal.1998
Cu	Untertiefenbach	300mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	208.6	.	seed	20.63	.	.	Lombietal.1998
Cu	Reisenberg	Control	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.7	4.9	21.0	26.0	.	seed	17.5	.	.	Lombietal.1998
Cu	Untertiefenbach	Control	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	17.67	.	seed	15.63	.	.	Lombietal.1998
Cu	Weyersdorf	Control	lab	40day	sunflower	Dicot	*Helianthusannuus*	6.9	3.5	10.9	13.3	.	seed	16.4	.	.	Lombietal.1998
Cu	Montana	milltown(reference)	field	resident	Grass	Monocot	.	.	.	.	17.9	.	leaf	7	.	1	Pascoeetal.1996
Cu	Montana	milltown(reference)	field	resident	forb	Dicot	.	.	.	.	17.9	.	leaf/stem	5.8	.	2	Pascoeetal.1996

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
Cu	Montana	milltow n	field	resident	Grass	Monocot	.	.	.	.	584.7	.	leaf	24.2	.	4	Pascoeetal.1996
Cu	Montana	milltow n	field	resident	forb	Dicot	.	.	.	.	584.7	.	leaf/stem	2.2	.	20	Pascoeetal.1996
Cu	Chile	Casablanca(CB)Reference	field	resident	Grape	Dicot	*Vitussp.*	.	.	.	27.9	.	fruit	.	U	.	Pinochetetal.1999
Cu	Chile	Catemu(C-2)	field	resident	Grape	Dicot	*Vitussp.*	.	.	.	113	.	fruit	4	.	.	Pinochetetal.1999
Cu	Chile	LaGreda(P-1)	field	resident	Grape	Dicot	*Vitussp.*	.	.	.	443	.	fruit	16.7	.	.	Pinochetetal.1999
Cu	Chile	Maitenes(P-2)	field	resident	Grape	Dicot	*Vitussp.*	.	.	.	382	.	fruit	18.4	.	.	Pinochetetal.1999
Cu	Chile	Nogales(P-4)	field	resident	Grape	Dicot	*Vitussp.*	.	.	.	59	.	fruit	2.5	.	.	Pinochetetal.1999
Cu	Chile	Panquehue(C-4)	field	resident	Grape	Dicot	*Vitussp.*	.	.	.	62	.	fruit	3.5	.	.	Pinochetetal.1999
Cu	Chile	Puchuncavi(P-3)	field	resident	Grape	Dicot	*Vitussp.*	.	.	.	143	.	fruit	5.3	.	.	Pinochetetal.1999
Cu	Chile	SanJose(C-2)	field	resident	Grape	Dicot	*Vitussp.*	.	.	.	127	.	fruit	4	.	.	Pinochetetal.1999
Cu	Chile	StaMargaritam(C-3)	field	resident	Grape	Dicot	*Vitussp.*	.	.	.	183	.	fruit	5.4	.	.	Pinochetetal.1999
Cu	Chile	Casablanca(CB)Reference	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	27.9	.	fruit	2.5	.	.	Pinochetetal.1999
Cu	Chile	Catemu(C-2)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	113	.	fruit	3.8	.	.	Pinochetetal.1999
Cu	Chile	LaGreda(P-1)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	443	.	fruit	10	.	.	Pinochetetal.1999
Cu	Chile	Maitenes(P-2)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	382	.	fruit	13.8	.	.	Pinochetetal.1999
Cu	Chile	Nogales(P-4)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	59	.	fruit	3.5	.	.	Pinochetetal.1999
Cu	Chile	Panquehue(C-4)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	62	.	fruit	6.8	.	.	Pinochetetal.1999
Cu	Chile	PPuchuncavi(P-3)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	143	.	fruit	2.3	.	.	Pinochetetal.1999
Cu	Chile	SanJose(C-2)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	127	.	fruit	6.6	.	.	Pinochetetal.1999
Cu	Chile	StaMargaritam(C-3)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	183	.	fruit	10.5	.	.	Pinochetetal.1999
Cu	Chile	LaGreda(P-1)	field	resident	plantain	Dicot	*Plantagolanceolata*	.	.	.	443	.	fruit/leaf	158	.	.	Pinochetetal.1999
Cu	Chile	Chagres(C-1b)	field	resident	Cabbage	Dicot	*Brassicaoleraceae*	.	.	.	140	.	leaf	13	.	.	Pinochetetal.1999
Cu	Chile	Catemu(C-2)	field	resident	Grass	Monocot	*Poaannoa*	.	.	.	113	.	leaf	16	.	.	Pinochetetal.1999
Cu	Chile	Chagres(C-1b)	field	resident	Grass	Monocot	*Poaannoa*	.	.	.	140	.	leaf	42	.	.	Pinochetetal.1999
Cu	Chile	LaGreda(P-1)	field	resident	Grass	Monocot	*Poaannoa*	.	.	.	443	.	leaf	90	.	.	Pinochetetal.1999
Cu	Chile	Maitenes(P-2)	field	resident	Grass	Monocot	*Poaannoa*	.	.	.	382	.	leaf	75	.	.	Pinochetetal.1999
Cu	Chile	Nogales(P-4)	field	resident	Grass	Monocot	*Poaannoa*	.	.	.	59	.	leaf	13	.	.	Pinochetetal.1999
Cu	Chile	Panquehue(C-4)	field	resident	Grass	Monocot	*Poaannoa*	.	.	.	62	.	leaf	28	.	.	Pinochetetal.1999
Cu	Chile	PPuchuncavi(P-3)	field	resident	Grass	Monocot	*Poaannoa*	.	.	.	143	.	leaf	34	.	.	Pinochetetal.1999
Cu	Chile	SanJose(C-2)	field	resident	Grass	Monocot	*Poaannoa*	.	.	.	127	.	leaf	16	.	.	Pinochetetal.1999
Cu	Chile	StaMargaritam(C-3)	field	resident	Grass	Monocot	*Poaannoa*	.	.	.	183	.	leaf	100	.	.	Pinochetetal.1999
Cu	Chile	Campiche(P-2b)	field	resident	Lettuce	Dicot	*Lactucasativa*	.	.	.	283	.	leaf	30	.	.	Pinochetetal.1999
Cu	Chile	Puchuncavi(P-3)	field	resident	Lettuce	Dicot	*Lactucasativa*	.	.	.	143	.	leaf	43.9	.	.	Pinochetetal.1999
Cu	Chile	Casablanca(CB)Reference	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	27.9	.	leaf	5.5	.	.	Pinochetetal.1999
Cu	Chile	Catemu(C-2)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	113	.	leaf	52	.	.	Pinochetetal.1999
Cu	Chile	LaGreda(P-1)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	443	.	leaf	204	.	.	Pinochetetal.1999
Cu	Chile	Maitenes(P-2)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	382	.	leaf	576	.	.	Pinochetetal.1999
Cu	Chile	Nogales(P-4)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	59	.	leaf	10	.	.	Pinochetetal.1999
Cu	Chile	Panquehue(C-4)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	62	.	leaf	24	.	.	Pinochetetal.1999
Cu	Chile	Puchuncavi(P-3)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	143	.	leaf	49	.	.	Pinochetetal.1999
Cu	Chile	SanJose(C-2)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	127	.	leaf	202	.	.	Pinochetetal.1999
Cu	Chile	StaMargaritam(C-3)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	183	.	leaf	156	.	.	Pinochetetal.1999
Cu	Chile	Campiche(P-2b)	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	283	.	leaf/stem	47	.	.	Pinochetetal.1999
Cu	Chile	Casablanca(CB)Reference	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	27.9	.	leaf/stem	9.3	.	.	Pinochetetal.1999
Cu	Chile	Catemu(C-2)	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	113	.	leaf/stem	24.1	.	.	Pinochetetal.1999
Cu	Chile	LaGreda(P-1)	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	443	.	leaf/stem	60	.	.	Pinochetetal.1999
Cu	Chile	Maitenes(P-2)	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	382	.	leaf/stem	56	.	.	Pinochetetal.1999
Cu	Chile	Nogales(P-4)	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	59	.	leaf/stem	8.6	.	.	Pinochetetal.1999
Cu	Chile	Panquehue(C-4)	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	62	.	leaf/stem	12.1	.	.	Pinochetetal.1999
Cu	Chile	PPuchuncavi(P-3)	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	143	.	leaf/stem	41	.	.	Pinochetetal.1999
Cu	Chile	SanJose(C-2)	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	127	.	leaf/stem	34	.	.	Pinochetetal.1999
Cu	Chile	StaMargaritam(C-3)	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	183	.	leaf/stem	82	.	.	Pinochetetal.1999
Cu	Chile	Puchuncavi(P-3)	field	resident	Celery	Dicot	*Apiumgraveolens*	.	.	.	143	.	leaf/stem	24	.	.	Pinochetetal.1999
Cu	Chile	SanJose(C-2)	field	resident	Celery	Dicot	*Apiumgraveolens*	.	.	.	127	.	leaf/stem	9.8	.	.	Pinochetetal.1999

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
Cu	Chile	Chagres(C-1b)	field	resident	Carrot	Dicot	*Daucascarota*	.	.	.	140	.	root	5	.	.	Pinochetetal.1999
Cu	Chile	Puchuncavi(P-3)	field	resident	Yuyo	Dicot	*Brassicarapa*	.	.	.	143	.	seed/stem	19	.	.	Pinochetetal.1999
Cu	Chile	Chagres(C-1b)	field	resident	Garlic	Monocot	*Alliumsativum*	.	.	.	140	.	stem	16	.	.	Pinochetetal.1999
Cu	Chile	Campiche(P-2b)	field	resident	Onion	Monocot	*Alliumcepa*	.	.	.	283	.	stem	5.8	.	.	Pinochetetal.1999
Cu	Chile	Campiche(P-2b)	field	resident	Potato	Dicot	*Solanumtuberosum*	.	.	.	283	.	root	7.5	.	.	Pinochetetal.1999
Cu	Oklahoma	GRID3	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.6	.	30.7	68	.	seed	21.6	.	.	PTI1995
Cu	Oklahoma	GRID4	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	5.95	.	20.95	77.4	.	seed	20.4	.	.	PTI1995
Cu	Oklahoma	TRAP1	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.4	.	14.1	186	.	seed	186	.	.	PTI1995
Cu	Oklahoma	TRAP2	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6	.	31.7	63.7	.	seed	63.7	.	.	PTI1995
Cu	Oklahoma	TRAP2	field	resident	Greenbriar	Monocot	*Smilaxbona-nox*	6	.	31.7	63.7	.	seed	63.7	.	.	PTI1995
Cu	Oklahoma	GRID1	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7.1	.	21.6	47.6	.	seed	6.3	.	.	PTI1995
Cu	Oklahoma	GRID2	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.1	.	36.3	180	.	seed	5.7	.	.	PTI1995
Cu	Oklahoma	GRID3	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.6	.	30.7	68	.	seed	6.7	.	.	PTI1995
Cu	Oklahoma	TERA	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7	.	32.6	11	.	seed	11	.	.	PTI1995
Cu	Oklahoma	TERB	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.5	.	20.3	20.05	.	seed	20.05	.	.	PTI1995
Cu	Oklahoma	TERC	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.8	.	18.8	20.75	.	seed	20.75	.	.	PTI1995
Cu	Oklahoma	GRID1	field	resident	Millet	Monocot	*Panicumvirgatum*	7.1	.	21.6	47.6	.	seed	8.8	.	.	PTI1995
Cu	Oklahoma	GRID2	field	resident	Millet	Monocot	*Panicumvirgatum*	6.1	.	36.3	180	.	seed	5.5	.	.	PTI1995
Cu	Oklahoma	GRID4	field	resident	Millet	Monocot	*Panicumvirgatum*	5.95	.	20.95	77.4	.	seed	5.2	.	.	PTI1995
Cu	Oklahoma	TERA	field	resident	Millet	Monocot	*Panicumvirgatum*	7	.	32.6	11	.	seed	11	.	.	PTI1995
Cu	Oklahoma	TERB	field	resident	Millet	Monocot	*Panicumvirgatum*	6.5	.	20.3	20.05	.	seed	20.05	.	.	PTI1995
Cu	Oklahoma	TERC	field	resident	Millet	Monocot	*Panicumvirgatum*	6.8	.	18.8	20.75	.	seed	20.75	.	.	PTI1995
Cu	Oklahoma	GRID2	field	resident	Pigw eed	Dicot	*Amaranthuspalmeri*	6.1	.	36.3	180	.	seed	6.1	.	.	PTI1995
Cu	Oklahoma	GRID1	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	7.1	.	21.6	47.6	.	seed	8.3	.	.	PTI1995
Cu	Oklahoma	GRID3	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	6.6	.	30.7	68	.	seed	12.9	.	.	PTI1995
Cu	Oklahoma	GRID4	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	5.95	.	20.95	77.4	.	seed	13.7	.	.	PTI1995
Cu	Oklahoma	TERA	field	resident	Ragw eed	Dicot	*Ambrosiapsilostachya*	7	.	32.6	11	.	seed	11	.	.	PTI1995
Cu	Oklahoma	TERB	field	resident	Ragw eed	Dicot	*Ambrosiapsilostachya*	6.5	.	20.3	20.05	.	seed	20.05	.	.	PTI1995
Cu	Oklahoma	TERC	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	6.8	.	18.8	20.75	.	seed	20.75	.	.	PTI1995
Cu	Oklahoma	TRAP1	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	6.4	.	14.1	186	.	seed	186	.	.	PTI1995
Cu	Oklahoma	TRAP1	field	resident	Ragw eed	Dicot	*Ambrosiatrifida*	6.4	.	14.1	186	.	seed	186	.	.	PTI1995
Cu	Oklahoma	TRAP2	field	resident	Ragw eed	Dicot	*Ambrosiatrifida*	6	.	31.7	63.7	.	seed	63.7	.	.	PTI1995
Cu	Wyoming	Reference	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	15.37	.	leaf	7.3	.	.	RamirezandRogers2000
Cu	Wyoming	Reference	field	resident	Brome	Monocot	*Bromussp.*	.	.	.	15.37	.	leaf	20.13	.	.	RamirezandRogers2000
Cu	Wyoming	StudyArea	field	resident	Brome	Monocot	*Bromussp.*	.	.	.	15.45	.	leaf	5.40	.	.	RamirezandRogers2000
Cu	Wyoming	StudyArea	field	resident	Dandelion	Dicot	*Taraxacumofficinale*	.	.	.	15.45	.	leaf	13	.	.	RamirezandRogers2000
Cu	Wyoming	StudyArea	field	resident	FoxtailBarley	Dicot	*Hordiumjubatum*	.	.	.	15.45	.	leaf	6.86	.	.	RamirezandRogers2000
Cu	Wyoming	Reference	field	resident	KentuckyBluegrass	Monocot	*PoaPratensis*	.	.	.	15.37	.	leaf	9.9	.	.	RamirezandRogers2000
Cu	Wyoming	StudyArea	field	resident	Pondw eed	Monocot	*Potamogetonsp*	.	.	.	0.01	.	leaf	4.06	.	.	RamirezandRogers2000
Cu	Canada	.	field	resident	Blueberry	Dicot	*Vacciniumangustifolium*	.	.	.	14	.	leaf	6.3	.	56	SheppardandEvenden1990
Cu	Colorado	.	field	resident	DevilsBitScabious	Dicot	*Succisapratensis*	6.48	.	.	17.6	.	leaf	30.5	.	15	SteinbornandBreen1999
Cu	Colorado	.	field	resident	Germander	Dicot	*Teucriumscorodonica*	6.34	.	.	2.5	.	leaf	42.07	.	15	SteinbornandBreen1999
Cu	Colorado	.	field	resident	Primrose	Dicot	*Primulavulgaris*	6.8	.	.	19.7	.	leaf	51.2	.	15	SteinbornandBreen1999
Cu	Colorado	.	field	resident	Moss	Bryophyte	*Rhytidiadelphusloreus*	7.13	.	.	6.58	.	leaf/stem	4.9	.	15	SteinbornandBreen1999
Cu	Colorado	.	field	resident	Stair-stepmoss	Bryophyte	*Hylocomiumsplendens*	6.54	.	.	11.3	.	leaf/stem	0.1	U	15	SteinbornandBreen1999
Cu	China	Futian	fielld	resident	Mangrove	Dicot	*Aegicerascorniculatum*	5.6	.	28.56	41.1	.	leaf	4.12	.	.	Tametal1995
Cu	China	Futian	fielld	resident	Mangrove	Dicot	*Kandeliacandel*	5.6	.	28.56	41.1	.	leaf	4.05	.	.	Tametal1995
Dibenz(ah)anthracene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.00043	.	leaf/stem	0.0001	.	.	Kipopoulouetal.1999
Dibenz(ah)anthracene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.00043	.	leaf/stem	.	.	.	Kipopoulouetal.1999
Dibenz(ah)anthracene	.	.	.	.	endive	.	.	.	.	.	0.00043	.	leaf/stem	0.00006	.	.	Kipopoulouetal.1999
Dibenz(ah)anthracene	.	.	.	.	leek	.	.	.	.	.	0.00043	.	leaf/stem	0.00005	.	.	Kipopoulouetal.1999
Dibenz(ah)anthracene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.00043	.	leaf/stem	0.00003	.	.	Kipopoulouetal.1999
Dibenz(ah)anthracene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.00043	.	root	.	.	.	Kipopoulouetal.1999
Dibenz(ah)anthracene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.00043	.	root	0.0001	.	.	Kipopoulouetal.1999

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
Dibenz(ah)anthracene	.	.	.	.	endive	.	.	.	.	.	0.00043	.	root	.	.	.	Kipopoulouetal.1999
Dibenz(ah)anthracene	.	.	.	.	leek	.	.	.	.	.	0.00043	.	root	.	.	.	Kipopoulouetal.1999
Dibenz(ah)anthracene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.00043	.	root	.	.	.	Kipopoulouetal.1999
Dibenz(ah)anthracene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0	.	leaf/stem	0	.	.	WildandJones1992
Dibenz(ah)anthracene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0	.	leaf/stem	0	.	.	WildandJones1992
Dibenz(ah)anthracene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0	.	leaf/stem	0	.	.	WildandJones1992
Dibenz(ah)anthracene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0	.	root	0	.	.	WildandJones1992
Dibenz(ah)anthracene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0	.	root	0.0002	.	.	WildandJones1992
Dibenz(ah)anthracene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0	.	root	0.0003	.	.	WildandJones1992
Fe	Oklahoma	GRID3	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.6	.	30.7	15500	.	seed	218	J	.	PTI1995
Fe	Oklahoma	GRID4	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	5.95	.	20.95	20450	.	seed	286	J	.	PTI1995
Fe	Oklahoma	TRAP1	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.4	.	14.1	27000	.	seed	27000	J	.	PTI1995
Fe	Oklahoma	TRAP2	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6	.	31.7	19300	.	seed	19300	J	.	PTI1995
Fe	Oklahoma	TRAP2	field	resident	Greenbriar	Monocot	*Smilaxbona-nox*	6	.	31.7	19300	.	seed	19300	J	.	PTI1995
Fe	Oklahoma	GRID1	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7.1	.	21.6	26100	.	seed	196	J	.	PTI1995
Fe	Oklahoma	GRID2	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.1	.	36.3	19800	.	seed	140	J	.	PTI1995
Fe	Oklahoma	GRID3	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	5.95	.	20.95	15500	.	seed	124	J	.	PTI1995
Fe	Oklahoma	TERA	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7	.	32.6	17350	.	seed	17350	.	.	PTI1995
Fe	Oklahoma	TERB	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.5	.	20.3	26600	.	seed	26600	.	.	PTI1995
Fe	Oklahoma	TERC	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.8	.	18.8	29300	.	seed	29300	J	.	PTI1995
Fe	Oklahoma	GRID1	field	resident	Millet	Monocot	*Panicumvirgatum*	7.1	.	21.6	26100	.	seed	206	J	.	PTI1995
Fe	Oklahoma	GRID2	field	resident	Millet	Monocot	*Panicumvirgatum*	6.1	.	36.3	19800	.	seed	160	J	.	PTI1995
Fe	Oklahoma	GRID4	field	resident	Millet	Monocot	*Panicumvirgatum*	5.95	.	20.95	20450	.	seed	68	J	.	PTI1995
Fe	Oklahoma	TERA	field	resident	Millet	Monocot	*Panicumvirgatum*	7	.	32.6	17350	.	seed	17350	.	.	PTI1995
Fe	Oklahoma	TERB	field	resident	Millet	Monocot	*Panicumvirgatum*	6.5	.	20.3	26600	.	seed	26600	.	.	PTI1995
Fe	Oklahoma	TERC	field	resident	Millet	Monocot	*Panicumvirgatum*	6.8	.	18.8	29300	.	seed	29300	J	.	PTI1995
Fe	Oklahoma	GRID2	field	resident	Pigw eed	Dicot	*Amaranthuspalmeri*	6.1	.	36.3	19800	.	seed	162	J	.	PTI1995
Fe	Oklahoma	GRID1	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	7.1	.	21.6	26100	.	seed	172	J	.	PTI1995
Fe	Oklahoma	GRID3	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	6.6	.	30.7	15500	.	seed	82	J	.	PTI1995
Fe	Oklahoma	GRID4	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	5.95	.	20.95	20450	.	seed	137	J	.	PTI1995
Fe	Oklahoma	TERA	field	resident	Ragw eed	Dicot	*Ambrosiapsilostachya*	7	.	32.6	17350	.	seed	17350	.	.	PTI1995
Fe	Oklahoma	TERB	field	resident	Ragw eed	Dicot	*Ambrosiapsilostachya*	6.5	.	20.3	26600	.	seed	26600	.	.	PTI1995
Fe	Oklahoma	TERC	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	6.8	.	18.8	29300	.	seed	29300	J	.	PTI1995
Fe	Oklahoma	TRAP1	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	6.4	.	14.1	27000	.	seed	27000	.	.	PTI1995
Fe	Oklahoma	TRAP1	field	resident	Ragw eed	Dicot	*Ambrosiatrifida*	6.4	.	14.1	27000	.	seed	27000	.	.	PTI1995
Fe	Oklahoma	TRAP2	field	resident	Ragw eed	Dicot	*Ambrosiatrifida*	6	.	31.7	19300	.	seed	19300	J	.	PTI1995
Fe	Canada	.	field	resident	Blueberry	Dicot	*Vacciniumangustifolium*	.	.	.	22000	.	leaf	100	.	64	SheppardandEvenden1990
Fl	GreatBritain	control	field	resident	Grass	Monocot	.	.	.	.	138.9	.	w holeplant	7.7	.	.	Andrew setal1989c
Fl	GreatBritain	tailings	field	resident	Grass	Monocot	.	.	.	.	142.3	.	w holeplant	510	.	.	Andrew setal1989c
Fluoranthene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.0073	.	leaf/stem	0.003	.	.	Kipopoulouetal.1999
Fluoranthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0073	.	leaf/stem	.	.	.	Kipopoulouetal.1999
Fluoranthene	.	.	.	.	endive	.	.	.	.	.	0.0073	.	leaf/stem	0.044	.	.	Kipopoulouetal.1999
Fluoranthene	.	.	.	.	leek	.	.	.	.	.	0.0073	.	leaf/stem	0.018	.	.	Kipopoulouetal.1999
Fluoranthene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.0073	.	leaf/stem	0.034	.	.	Kipopoulouetal.1999
Fluoranthene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.0073	.	root	.	.	.	Kipopoulouetal.1999
Fluoranthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0073	.	root	0.011	.	.	Kipopoulouetal.1999
Fluoranthene	.	.	.	.	endive	.	.	.	.	.	0.0073	.	root	.	.	.	Kipopoulouetal.1999
Fluoranthene	.	.	.	.	leek	.	.	.	.	.	0.0073	.	root	.	.	.	Kipopoulouetal.1999
Fluoranthene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.0073	.	root	.	.	.	Kipopoulouetal.1999
Fluoranthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.00915	.	leaf/stem	0.025	.	.	WildandJones1992
Fluoranthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0279	.	leaf/stem	0.024	.	.	WildandJones1992
Fluoranthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.09315	.	leaf/stem	0.025	.	.	WildandJones1992
Fluoranthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.00915	.	root	0.0001	.	.	WildandJones1992
Fluoranthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0279	.	root	0.0011	.	.	WildandJones1992
Fluoranthene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.09315	.	root	0.0011	.	.	WildandJones1992

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
fluorene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.101	.	leaf/stem	0.0011	.	.	Kipopoulouetal.1999
fluorene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.101	.	leaf/stem	.	.	.	Kipopoulouetal.1999
fluorene	.	.	.	.	endive	.	.	.	.	.	0.101	.	leaf/stem	0.0057	.	.	Kipopoulouetal.1999
fluorene	.	.	.	.	leek	.	.	.	.	.	0.101	.	leaf/stem	0.0026	.	.	Kipopoulouetal.1999
fluorene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.101	.	leaf/stem	0.0058	.	.	Kipopoulouetal.1999
fluorene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.101	.	root	.	.	.	Kipopoulouetal.1999
fluorene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.101	.	root	0.0037	.	.	Kipopoulouetal.1999
fluorene	.	.	.	.	endive	.	.	.	.	.	0.101	.	root	.	.	.	Kipopoulouetal.1999
fluorene	.	.	.	.	leek	.	.	.	.	.	0.101	.	root	.	.	.	Kipopoulouetal.1999
fluorene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.101	.	root	.	.	.	Kipopoulouetal.1999
Hg	inorganicmercury	.	lab	maturity	Squash	Dicot	*Cucurbitasp.*	6.5	.	.	0.4058	.	fruit	0.0087	.	3	Cappon1987
Hg	methylmercury	.	lab	maturity	Squash	Dicot	*Cucurbitasp.*	6.5	.	.	0.0229	.	fruit	.	U	3	Cappon1987
Hg	inorganicmercury	.	lab	maturity	cucumber	Dicot	*Cucumissativus*	6.5	.	.	0.4058	.	fruit	0.0029	.	4	Cappon1987
Hg	methylmercury	.	lab	maturity	cucumber	Dicot	*Cucumissativus*	6.5	.	.	0.0229	.	fruit	.	U	4	Cappon1987
Hg	inorganicmercury	.	lab	maturity	Pepper	Dicot	*Capsicumannuum*	6.5	.	.	0.4058	.	fruit	0.0077	.	8	Cappon1987
Hg	methylmercury	.	lab	maturity	Pepper	Dicot	*Capsicumannuum*	6.5	.	.	0.0229	.	fruit	0.0005	.	8	Cappon1987
Hg	inorganicmercury	.	lab	maturity	tomato	Dicot	*Lycopersiconesculentum*	6.5	.	.	0.4058	.	fruit	0.0241	.	8	Cappon1987
Hg	methylmercury	.	lab	maturity	tomato	Dicot	*Lycopersiconesculentum*	6.5	.	.	0.0229	.	fruit	0.0024	.	8	Cappon1987
Hg	inorganicmercury	.	lab	maturity	Broccoli	Dicot	*Brassicaoleracea*	6.5	.	.	0.4058	.	leaf	0.0407	.	8	Cappon1987
Hg	methylmercury	.	lab	maturity	Broccoli	Dicot	*Brassicaoleracea*	6.5	.	.	0.0229	.	leaf	0.0088	.	8	Cappon1987
Hg	inorganicmercury	.	lab	maturity	Cabbage	Dicot	*Brassicaoleracea*	6.5	.	.	0.4058	.	leaf	0.0528	.	8	Cappon1987
Hg	methylmercury	.	lab	maturity	Cabbage	Dicot	*Brassicaoleracea*	6.5	.	.	0.0229	.	leaf	0.0116	.	8	Cappon1987
Hg	inorganicmercury	.	lab	maturity	Lettuce	Dicot	*Lactucasativa*	6.5	.	.	0.4058	.	leaf	0.1095	.	12	Cappon1987
Hg	methylmercury	.	lab	maturity	Lettuce	Dicot	*Lactucasativa*	6.5	.	.	0.0229	.	leaf	0.0298	.	12	Cappon1987
Hg	inorganicmercury	.	lab	maturity	beet	Dicot	*Betavulgaris*	6.5	.	.	0.4058	.	leaf	0.0549	.	18	Cappon1987
Hg	methylmercury	.	lab	maturity	beet	Dicot	*Betavulgaris*	6.5	.	.	0.0229	.	leaf	0.0095	.	18	Cappon1987
Hg	inorganicmercury	.	lab	maturity	Turnip	Dicot	*Brassicarapa*	6.5	.	.	0.4058	.	root	0.0106	.	18	Cappon1987
Hg	methylmercury	.	lab	maturity	Turnip	Dicot	*Brassicarapa*	6.5	.	.	0.0229	.	root	0.0003	.	18	Cappon1987
Hg	inorganicmercury	.	lab	maturity	spinach	Dicot	*Spinaciaoleracea*	6.5	.	.	0.4058	.	leaf	0.0565	.	24	Cappon1987
Hg	methylmercury	.	lab	maturity	spinach	Dicot	*Spinaciaoleracea*	6.5	.	.	0.0229	.	leaf	0.0170	.	24	Cappon1987
Hg	inorganicmercury	.	lab	maturity	Onion	Monocot	*Alliumcepa*	6.5	.	.	0.4058	.	stem	0.0296	.	24	Cappon1987
Hg	methylmercury	.	lab	maturity	Onion	Monocot	*Alliumcepa*	6.5	.	.	0.0229	.	stem	0.0066	.	24	Cappon1987
Hg	inorganicmercury	.	lab	maturity	beet	Dicot	*Betasp.*	6.5	.	.	0.4058	.	root	0.0222	.	36	Cappon1987
Hg	methylmercury	.	lab	maturity	beet	Dicot	*Betasp.*	6.5	.	.	0.0229	.	root	0.0052	.	36	Cappon1987
Hg	inorganicmercury	.	lab	maturity	Radish	Dicot	*Raphanussativus*	6.5	.	.	0.4058	.	root	0.0229	.	36	Cappon1987
Hg	methylmercury	.	lab	maturity	Radish	Dicot	*Raphanussativus*	6.5	.	.	0.0229	.	root	0.0021	.	36	Cappon1987
Hg	inorganicmercury	.	lab	maturity	Lettuce	Dicot	*Lactucasativa*	6.5	.	.	0.4058	.	leaf	0.061	.	40	Cappon1987
Hg	methylmercury	.	lab	maturity	Lettuce	Dicot	*Lactucasativa*	6.5	.	.	0.0229	.	leaf	0.0134	.	40	Cappon1987
Hg	inorganicmercury	.	lab	maturity	Bean	Dicot	*Phaselousvulgaris*	6.5	.	.	0.4058	.	seed	0.0043	.	40	Cappon1987
Hg	methylmercury	.	lab	maturity	Bean	Dicot	*Phaselousvulgaris*	6.5	.	.	0.0229	.	seed	.	U	40	Cappon1987
Hg	inorganicmercury	.	lab	maturity	Carrot	Dicot	*Daucascarota*	6.5	.	.	0.4058	.	root	0.0105	.	48	Cappon1987
Hg	methylmercury	.	lab	maturity	Carrot	Dicot	*Daucascarota*	6.5	.	.	0.0229	.	root	0.0027	.	48	Cappon1987
Hg	Oklahoma	GRID2	field	resident	Millet	Monocot	*Panicumvirgatum*	6.1	.	36.3	0.19	.	seed	0.09	.	.	PTI1995
Hg	Wyoming	Reference	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	0.01	.	leaf	0.0045	.	.	RamirezandRogers2000
Hg	Wyoming	Reference	field	resident	Brome	Monocot	*Bromussp.*	.	.	.	0.01	.	leaf	0.01	.	.	RamirezandRogers2000
Hg	Wyoming	StudyArea	field	resident	Brome	Monocot	*Bromussp.*	.	.	.	0.02	.	leaf	0.01	.	.	RamirezandRogers2000
Hg	Wyoming	StudyArea	field	resident	Dandelion	Dicot	*Taraxacumofficinale*	.	.	.	0.02	.	leaf	0.02	.	.	RamirezandRogers2000
Hg	Wyoming	StudyArea	field	resident	FoxtailBarley	Dicot	*Hordiumjubatum*	.	.	.	0.02	.	leaf	0.01	.	.	RamirezandRogers2000
Hg	Wyoming	Reference	field	resident	KentuckyBluegrass	Monocot	*PoaPratensis*	.	.	.	0.01	.	leaf	0.01	.	.	RamirezandRogers2000
Hg	inorganicmercury(mercuricchloride)	0	lab	maturity	Bean	Dicot	*Phaselousvulgaris*	5.7	.	24.6	0	.	seed	0.0005	.	.	Semuetal.1985
Hg	methylmercury(Aretan)	0	lab	maturity	Bean	Dicot	*Phaselousvulgaris*	5.7	.	24.6	0	.	seed	0.0005	.	.	Semuetal.1985
Hg	inorganicmercury(mercuricchloride)	1	lab	maturity	Bean	Dicot	*Phaselousvulgaris*	5.7	.	24.6	1	.	seed	0.0003	.	.	Semuetal.1985
Hg	methylmercury(Aretan)	1	lab	maturity	Bean	Dicot	*Phaselousvulgaris*	5.7	.	24.6	1	.	seed	0.0003	.	.	Semuetal.1985
Hg	inorganicmercury(mercuricchloride)	5	lab	maturity	Bean	Dicot	*Phaselousvulgaris*	5.7	.	24.6	5	.	seed	0.0013	.	.	Semuetal.1985

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
Hg	methylmercury(Aretan)	5	lab	maturity	Bean	Dicot	*Phaselousvulgaris*	5.7	.	24.6	5	.	seed	0.0011	.	.	Semuetal.1985
Hg	inorganicmercury(mercuricchloride)	50	lab	maturity	Bean	Dicot	*Phaselousvulgaris*	5.7	.	24.6	50	.	seed	.	.	.	Semuetal.1985
Hg	methylmercury(Aretan)	50	lab	maturity	Bean	Dicot	*Phaselousvulgaris*	5.7	.	24.6	50	.	seed	.	.	.	Semuetal.1985
Hg	inorganicmercury(mercuricchloride)	0	lab	maturity	wheat	Monocot	*Triticumaestivum*	5.7	.	24.6	0	.	seed	0.00001	.	.	Semuetal.1985
Hg	methylmercury(Aretan)	0	lab	maturity	wheat	Monocot	*Triticumaestivum*	5.7	.	24.6	0	.	seed	0.00001	.	.	Semuetal.1985
Hg	inorganicmercury(mercuricchloride)	1	lab	maturity	wheat	Monocot	*Triticumaestivum*	5.7	.	24.6	1	.	seed	0.0093	.	.	Semuetal.1985
Hg	methylmercury(Aretan)	1	lab	maturity	wheat	Monocot	*Triticumaestivum*	5.7	.	24.6	1	.	seed	0.00001	.	.	Semuetal.1985
Hg	inorganicmercury(mercuricchloride)	5	lab	maturity	wheat	Monocot	*Triticumaestivum*	5.7	.	24.6	5	.	seed	0.0122	.	.	Semuetal.1985
Hg	methylmercury(Aretan)	5	lab	maturity	wheat	Monocot	*Triticumaestivum*	5.7	.	24.6	5	.	seed	0.00006	.	.	Semuetal.1985
Hg	inorganicmercury(mercuricchloride)	50	lab	maturity	wheat	Monocot	*Triticumaestivum*	5.7	.	24.6	50	.	seed	0.2364	.	.	Semuetal.1985
Hg	methylmercury(Aretan)	50	lab	maturity	wheat	Monocot	*Triticumaestivum*	5.7	.	24.6	50	.	seed	0.0056	.	.	Semuetal.1985
Indeno(123cd)pyrene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.0021	.	leaf/stem	0.00015	.	.	Kipopoulouetal.1999
Indeno(123cd)pyrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0021	.	leaf/stem	.	.	.	Kipopoulouetal.1999
Indeno(123cd)pyrene	.	.	.	.	endive	.	.	.	.	.	0.0021	.	leaf/stem	0.00031	.	.	Kipopoulouetal.1999
Indeno(123cd)pyrene	.	.	.	.	leek	.	.	.	.	.	0.0021	.	leaf/stem	.	.	.	Kipopoulouetal.1999
Indeno(123cd)pyrene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.0021	.	leaf/stem	.	.	.	Kipopoulouetal.1999
Indeno(123cd)pyrene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.0021	.	root	.	.	.	Kipopoulouetal.1999
Indeno(123cd)pyrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0021	.	root	0.00028	.	.	Kipopoulouetal.1999
Indeno(123cd)pyrene	.	.	.	.	endive	.	.	.	.	.	0.0021	.	root	.	.	.	Kipopoulouetal.1999
Indeno(123cd)pyrene	.	.	.	.	leek	.	.	.	.	.	0.0021	.	root	.	.	.	Kipopoulouetal.1999
Indeno(123cd)pyrene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.0021	.	root	.	.	.	Kipopoulouetal.1999
K	Oklahoma	GRID3	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.6	.	30.7	1410	.	seed	21800	J	.	PTI1995
K	Oklahoma	GRID4	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	5.95	.	20.95	2325	.	seed	18900	.	.	PTI1995
K	Oklahoma	TRAP1	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.4	.	14.1	1980	.	seed	1980	.	.	PTI1995
K	Oklahoma	TRAP2	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6	.	31.7	2320	.	seed	2320	.	.	PTI1995
K	Oklahoma	TRAP2	field	resident	Greenbriar	Monocot	*Smilaxbona-nox*	6	.	31.7	2320	.	seed	2320	.	.	PTI1995
K	Oklahoma	GRID1	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7.1	.	21.6	1400	.	seed	5390	.	.	PTI1995
K	Oklahoma	GRID2	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.1	.	36.3	1850	.	seed	4120	J	.	PTI1995
K	Oklahoma	GRID3	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.6	.	30.7	1410	.	seed	5330	J	.	PTI1995
K	Oklahoma	TERA	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7	.	32.6	1560	.	seed	1560	.	.	PTI1995
K	Oklahoma	TERB	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.5	.	20.3	1845	.	seed	1845	.	.	PTI1995
K	Oklahoma	TERC	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.8	.	18.8	3735	.	seed	3735	J	.	PTI1995
K	Oklahoma	GRID1	field	resident	Millet	Monocot	*Panicumvirgatum*	7.1	.	21.6	1400	.	seed	3990	.	.	PTI1995
K	Oklahoma	GRID2	field	resident	Millet	Monocot	*Panicumvirgatum*	6.1	.	36.3	1850	.	seed	1620	J	.	PTI1995
K	Oklahoma	GRID4	field	resident	Millet	Monocot	*Panicumvirgatum*	5.95	.	20.95	2325	.	seed	3800	.	.	PTI1995
K	Oklahoma	TERA	field	resident	Millet	Monocot	*Panicumvirgatum*	7	.	32.6	1560	.	seed	1560	.	.	PTI1995
K	Oklahoma	TERB	field	resident	Millet	Monocot	*Panicumvirgatum*	6.5	.	20.3	1845	.	seed	1845	.	.	PTI1995
K	Oklahoma	TERC	field	resident	Millet	Monocot	*Panicumvirgatum*	6.8	.	18.8	3735	.	seed	3735	J	.	PTI1995
K	Oklahoma	GRID2	field	resident	Pigweed	Dicot	*Amaranthuspalmeri*	6.1	.	36.3	1850	.	seed	44100	J	.	PTI1995
K	Oklahoma	GRID1	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	7.1	.	21.6	1400	.	seed	17900	.	.	PTI1995
K	Oklahoma	GRID3	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.6	.	30.7	1410	.	seed	18100	J	.	PTI1995
K	Oklahoma	GRID4	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	5.95	.	20.95	2325	.	seed	18400	.	.	PTI1995
K	Oklahoma	TERA	field	resident	Ragweed	Dicot	*Ambrosiapsilostachya*	7	.	32.6	1560	.	seed	1560	.	.	PTI1995
K	Oklahoma	TERB	field	resident	Ragweed	Dicot	*Ambrosiapsilostachya*	6.5	.	20.3	1845	.	seed	1845	.	.	PTI1995
K	Oklahoma	TERC	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.8	.	18.8	3735	.	seed	3735	J	.	PTI1995
K	Oklahoma	TRAP1	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.4	.	14.1	1980	.	seed	1980	.	.	PTI1995
K	Oklahoma	TRAP1	field	resident	Ragweed	Dicot	*Ambrosiatrifida*	6.4	.	14.1	1980	.	seed	1980	.	.	PTI1995
K	Oklahoma	TRAP2	field	resident	Ragweed	Dicot	*Ambrosiatrifida*	6	.	31.7	2320	.	seed	2320	.	.	PTI1995
Mg	Oklahoma	GRID3	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.6	.	30.7	1340	.	seed	3940	.	.	PTI1995
Mg	Oklahoma	GRID4	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	5.95	.	20.95	2120	.	seed	4240	.	.	PTI1995
Mg	Oklahoma	TRAP1	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.4	.	14.1	2530	.	seed	2530	.	.	PTI1995
Mg	Oklahoma	TRAP2	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6	.	31.7	2140	.	seed	2140	.	.	PTI1995
Mg	Oklahoma	TRAP2	field	resident	Greenbriar	Monocot	*Smilaxbona-nox*	6	.	31.7	2140	.	seed	2140	.	.	PTI1995
Mg	Oklahoma	GRID1	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7.1	.	21.6	2850	.	seed	1350	.	.	PTI1995

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
Mg	Oklahoma	GRID2	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.1	.	36.3	1750	.	seed	824	.	.	PTI1995
Mg	Oklahoma	GRID3	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.6	.	30.7	1340	.	seed	882	.	.	PTI1995
Mg	Oklahoma	TERA	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7	.	32.6	1420	.	seed	1420	.	.	PTI1995
Mg	Oklahoma	TERB	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.5	.	20.3	1950	.	seed	1950	.	.	PTI1995
Mg	Oklahoma	TERC	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.8	.	18.8	3505	.	seed	3505	.	.	PTI1995
Mg	Oklahoma	GRID1	field	resident	Millet	Monocot	*Panicumvirgatum*	7.1	.	21.6	2850	.	seed	1860	.	.	PTI1995
Mg	Oklahoma	GRID2	field	resident	Millet	Monocot	*Panicumvirgatum*	6.1	.	36.3	1750	.	seed	1220	.	.	PTI1995
Mg	Oklahoma	GRID4	field	resident	Millet	Monocot	*Panicumvirgatum*	5.95	.	20.95	2120	.	seed	1640	.	.	PTI1995
Mg	Oklahoma	TERA	field	resident	Millet	Monocot	*Panicumvirgatum*	7	.	32.6	1420	.	seed	1420	.	.	PTI1995
Mg	Oklahoma	TERB	field	resident	Millet	Monocot	*Panicumvirgatum*	6.5	.	20.3	1950	.	seed	1950	.	.	PTI1995
Mg	Oklahoma	TERC	field	resident	Millet	Monocot	*Panicumvirgatum*	6.8	.	18.8	3505	.	seed	3505	.	.	PTI1995
Mg	Oklahoma	GRID2	field	resident	Pigweed	Dicot	*Amaranthuspalmeri*	6.1	.	36.3	1750	.	seed	2510	.	.	PTI1995
Mg	Oklahoma	GRID1	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	7.1	.	21.6	2850	.	seed	6880	.	.	PTI1995
Mg	Oklahoma	GRID3	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.6	.	30.7	1340	.	seed	4640	.	.	PTI1995
Mg	Oklahoma	GRID4	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	5.95	.	20.95	2120	.	seed	5110	.	.	PTI1995
Mg	Oklahoma	TERA	field	resident	Ragweed	Dicot	*Ambrosiapsilostachya*	7	.	32.6	1420	.	seed	1420	.	.	PTI1995
Mg	Oklahoma	TERB	field	resident	Ragweed	Dicot	*Ambrosiapsilostachya*	6.5	.	20.3	1950	.	seed	1950	.	.	PTI1995
Mg	Oklahoma	TERC	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.8	.	18.8	3505	.	seed	3505	.	.	PTI1995
Mg	Oklahoma	TRAP1	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.4	.	14.1	2530	.	seed	2530	.	.	PTI1995
Mg	Oklahoma	TRAP1	field	resident	Ragweed	Dicot	*Ambrosiatrifida*	6.4	.	14.1	2530	.	seed	2530	.	.	PTI1995
Mg	Oklahoma	TRAP2	field	resident	Ragweed	Dicot	*Ambrosiatrifida*	6	.	31.7	2140	.	seed	2140	.	.	PTI1995
Mg	Wyoming	Reference	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	4137.67	.	leaf	4180	.	.	RamirezandRogers2000
Mg	Wyoming	Reference	field	resident	Brome	Monocot	*Bromussp.*	.	.	.	4137.67	.	leaf	1974.91	.	.	RamirezandRogers2000
Mg	Wyoming	StudyArea	field	resident	Brome	Monocot	*Bromussp.*	.	.	.	3965.26	.	leaf	1872.86	.	.	RamirezandRogers2000
Mg	Wyoming	StudyArea	field	resident	Dandelion	Dicot	*Taraxacumofficinale*	.	.	.	3965.26	.	leaf	3750	.	.	RamirezandRogers2000
Mg	Wyoming	StudyArea	field	resident	FoxtailBarley	Dicot	*Hordiumjubatum*	.	.	.	3965.26	.	leaf	977.99	.	.	RamirezandRogers2000
Mg	Wyoming	Reference	field	resident	KentuckyBluegrass	Monocot	*PoaPratensis*	.	.	.	4137.67	.	leaf	2630	.	.	RamirezandRogers2000
Mg	Wyoming	StudyArea	field	resident	Pondweed	Monocot	*Potamogetonsp*	.	.	.	96.60	.	leaf	5252.43	.	.	RamirezandRogers2000
Mg	Canada	.	field	resident	Blueberry	Dicot	*Vacciniumangustifolium*	.	.	.	4400	.	leaf	2200	.	64	SheppardandEvenden1990
Mn	California	Kesterson	field	resident	BirdfootTrefoil	Dicot	*Lotuscorniculatus*	.	.	.	663.5	.	leaf/stem	37	.	.	Banuelosetal.1999
Mn	California	Kesterson	field	resident	Mustard	Dicot	*Brassicajuncea*	.	.	.	663.5	.	leaf/stem	47	.	.	Banuelosetal.1999
Mn	California	Kesterson	field	resident	Rose-Mallow	Dicot	*Hibiscuscanabinus*	.	.	.	663.5	.	leaf/stem	230	.	.	Banuelosetal.1999
Mn	California	Kesterson	field	resident	TallFescue	Monocot	*Festucaarundinacea*	.	.	.	663.5	.	leaf/stem	46	.	.	Banuelosetal.1999
Mn	California	Kesterson	field	resident	BirdfootTrefoil	Dicot	*Lotuscorniculatus*	.	.	.	663.5	.	root	23	.	.	Banuelosetal.1999
Mn	California	Kesterson	field	resident	Rose-Mallow	Dicot	*Hibiscuscanabinus*	.	.	.	663.5	.	root	35	.	.	Banuelosetal.1999
Mn	California	Kesterson	field	resident	TallFescue	Monocot	*Festucaarundinacea*	.	.	.	7	.	root	0.9	.	.	Banuelosetal.1999
Mn	Japan	.	lab	30day	Japanesewhitebirch	Dicot	*Betulaplatyphylla*	.	.	.	.	.	leaf	0.018	.	.	Kitaoetal.2000
Mn	Oklahoma	GRID3	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.6	.	30.7	455	.	seed	27.6	.	.	PTI1995
Mn	Oklahoma	GRID4	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	5.95	.	20.95	583	.	seed	62.5	.	.	PTI1995
Mn	Oklahoma	TRAP1	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.4	.	14.1	615	.	seed	615	.	.	PTI1995
Mn	Oklahoma	TRAP2	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6	.	31.7	524	.	seed	524	.	.	PTI1995
Mn	Oklahoma	TRAP2	field	resident	Greenbriar	Monocot	*Smilaxbona-nox*	6	.	31.7	524	.	seed	524	.	.	PTI1995
Mn	Oklahoma	GRID1	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7.1	.	21.6	486	.	seed	29.8	.	.	PTI1995
Mn	Oklahoma	GRID2	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.1	.	36.3	578	.	seed	31.8	.	.	PTI1995
Mn	Oklahoma	GRID3	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.6	.	30.7	455	.	seed	25.4	.	.	PTI1995
Mn	Oklahoma	TERA	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7	.	32.6	219.5	.	seed	219.5	.	.	PTI1995
Mn	Oklahoma	TERB	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.5	.	20.3	254	.	seed	254	.	.	PTI1995
Mn	Oklahoma	TERC	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.8	.	18.8	1145	.	seed	1145	.	.	PTI1995
Mn	Oklahoma	GRID1	field	resident	Millet	Monocot	*Panicumvirgatum*	7.1	.	21.6	486	.	seed	69.3	.	.	PTI1995
Mn	Oklahoma	GRID2	field	resident	Millet	Monocot	*Panicumvirgatum*	6.1	.	36.3	578	.	seed	66.5	.	.	PTI1995
Mn	Oklahoma	GRID4	field	resident	Millet	Monocot	*Panicumvirgatum*	5.95	.	20.95	583	.	seed	74.6	.	.	PTI1995
Mn	Oklahoma	TERA	field	resident	Millet	Monocot	*Panicumvirgatum*	7	.	32.6	219.5	.	seed	219.5	.	.	PTI1995
Mn	Oklahoma	TERB	field	resident	Millet	Monocot	*Panicumvirgatum*	6.5	.	20.3	254	.	seed	254	.	.	PTI1995
Mn	Oklahoma	TERC	field	resident	Millet	Monocot	*Panicumvirgatum*	6.8	.	18.8	1145	.	seed	1145	.	.	PTI1995

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
Mn	Oklahoma	GRID2	field	resident	Pigweed	Dicot	*Amaranthuspalmeri*	6.1	.	36.3	578	.	seed	14.2	.	.	PTI1995
Mn	Oklahoma	GRID1	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	7.1	.	21.6	486	.	seed	19.8	.	.	PTI1995
Mn	Oklahoma	GRID3	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.6	.	30.7	455	.	seed	11.7	.	.	PTI1995
Mn	Oklahoma	GRID4	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	5.95	.	20.95	583	.	seed	15.6	.	.	PTI1995
Mn	Oklahoma	TERA	field	resident	Ragweed	Dicot	*Ambrosiapsilostachya*	7	.	32.6	219.5	.	seed	219.5	.	.	PTI1995
Mn	Oklahoma	TERB	field	resident	Ragweed	Dicot	*Ambrosiapsilostachya*	6.5	.	20.3	254	.	seed	254	.	.	PTI1995
Mn	Oklahoma	TERC	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.8	.	18.8	1145	.	seed	1145	.	.	PTI1995
Mn	Oklahoma	TRAP1	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.4	.	14.1	615	.	seed	615	.	.	PTI1995
Mn	Oklahoma	TRAP1	field	resident	Ragweed	Dicot	*Ambrosiatrifida*	6.4	.	14.1	615	.	seed	615	.	.	PTI1995
Mn	Oklahoma	TRAP2	field	resident	Ragweed	Dicot	*Ambrosiatrifida*	6	.	31.7	524	.	seed	524	.	.	PTI1995
Mn	Wyoming	Reference	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	226.19	.	leaf	39.4	.	.	RamirezandRogers2000
Mn	Wyoming	Reference	field	resident	Brome	Monocot	*Bromussp.*	.	.	.	226.19	.	leaf	52.13	.	.	RamirezandRogers2000
Mn	Wyoming	StudyArea	field	resident	Brome	Monocot	*Bromussp.*	.	.	.	12.18	.	leaf	124.50	.	.	RamirezandRogers2000
Mn	Wyoming	StudyArea	field	resident	Dandelion	Dicot	*Taraxacumofficinale*	.	.	.	212.88	.	leaf	135	.	.	RamirezandRogers2000
Mn	Wyoming	StudyArea	field	resident	FoxtailBarley	Dicot	*Hordiumjubatum*	.	.	.	212.80	.	leaf	72.49	.	.	RamirezandRogers2000
Mn	Wyoming	Reference	field	resident	KentuckyBluegrass	Monocot	*PoaPratensis*	.	.	.	226.19	.	leaf	69.9	.	.	RamirezandRogers2000
Mn	Wyoming	StudyArea	field	resident	Pondweed	Monocot	*Potamogetonsp*	.	.	.	0.29	.	leaf	2265.81	.	.	RamirezandRogers2000
Mn	Canada	.	field	resident	Blueberry	Dicot	*Vacciniumangustifolium*	.	.	.	400	.	leaf	1500	.	64	SheppardandEvenden1990
Mo	California	Kesterson	field	resident	BirdfootTrefoil	Dicot	*Lotuscorniculatus*	.	.	.	0.9	.	leaf/stem	0.1	.	.	Banuelosetal.1999
Mo	California	Kesterson	field	resident	Mustard	Dicot	*Brassicajuncea*	.	.	.	0.9	.	leaf/stem	0.4	.	.	Banuelosetal.1999
Mo	California	Kesterson	field	resident	Rose-Mallow	Dicot	*Hibiscuscanabinus*	.	.	.	0.9	.	leaf/stem	1.1	.	.	Banuelosetal.1999
Mo	California	Kesterson	field	resident	TallFescue	Monocot	*Festucaarundinacea*	.	.	.	0.9	.	leaf/stem	0.1	.	.	Banuelosetal.1999
Mo	California	Kesterson	field	resident	BirdfootTrefoil	Dicot	*Lotuscorniculatus*	.	.	.	0.9	.	root	0.3	.	.	Banuelosetal.1999
Mo	California	Kesterson	field	resident	Rose-Mallow	Dicot	*Hibiscuscanabinus*	.	.	.	0.9	.	root	1.1	.	.	Banuelosetal.1999
Mo	California	Kesterson	field	resident	TallFescue	Monocot	*Festucaarundinacea*	.	.	.	0.9	.	root	0.1	.	.	Banuelosetal.1999
Mo	California	Kesterson	field	248days	Grass	Monocot	*Elytrigiapontica*	7.8	.	14	7.9	.	leaf/stem	25.9	.	.	Retanaetal.1993
Mo	California	Kesterson	field	248days	Grass	Monocot	*Oryzopsishymenoides*	7.8	.	14	7.9	.	leaf/stem	24.7	.	.	Retanaetal.1993
Mo	California	Kesterson	field	248days	Grass	Monocot	*Sporobolusairoides*	7.8	.	14	7.9	.	leaf/stem	10.1	.	.	Retanaetal.1993
Mo	California	Kesterson	field	248days	Seaccumulator	Dicot	*Astragalusbisulcatus*	7.8	.	14	7.9	.	leaf/stem	43.9	.	.	Retanaetal.1993
Mo	California	Kesterson	field	248days	Seaccumulator	Dicot	*Astragalusracemosus*	7.8	.	14	7.9	.	leaf/stem	18.2	.	.	Retanaetal.1993
Mo	California	Kesterson	field	248days	Grass	Monocot	*Elytrigiapontica*	7.8	.	14	7.9	.	root	15.3	.	.	Retanaetal.1993
Mo	California	Kesterson	field	248days	Grass	Monocot	*Oryzopsishymenoides*	7.8	.	14	7.9	.	root	24.6	.	.	Retanaetal.1993
Mo	California	Kesterson	field	248days	Grass	Monocot	*Sporobolusairoides*	7.8	.	14	7.9	.	root	11.6	.	.	Retanaetal.1993
Mo	California	Kesterson	field	248days	Seaccumulator	Dicot	*Astragalusbisulcatus*	7.8	.	14	7.9	.	root	406	.	.	Retanaetal.1993
Mo	California	Kesterson	field	248days	Seaccumulator	Dicot	*Astragalusracemosus*	7.8	.	14	7.9	.	root	184	.	.	Retanaetal.1993
Mo	Canada	.	field	resident	Blueberry	Dicot	*Vacciniumangustifolium*	.	.	.	2.3	.	leaf	0.19	.	16	SheppardandEvenden1990
Na	Oklahoma	GRID1	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7.1	.	21.6	148	.	seed	89	.	.	PTI1995
Na	Oklahoma	GRID2	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.1	.	36.3	49.3	.	seed	13	.	.	PTI1995
Na	Oklahoma	GRID3	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.6	.	30.7	86.2	.	seed	18	.	.	PTI1995
Na	Oklahoma	TERA	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7	.	32.6	41.6	.	seed	41.6	.	.	PTI1995
Na	Oklahoma	GRID1	field	resident	Millet	Monocot	*Panicumvirgatum*	7.1	.	21.6	148	.	seed	176	.	.	PTI1995
Na	Oklahoma	GRID2	field	resident	Millet	Monocot	*Panicumvirgatum*	6.1	.	36.3	49.3	.	seed	20	.	.	PTI1995
Na	Oklahoma	GRID4	field	resident	Millet	Monocot	*Panicumvirgatum*	5.95	.	20.95	61.4	.	seed	15	.	.	PTI1995
Na	Oklahoma	TERA	field	resident	Millet	Monocot	*Panicumvirgatum*	7	.	32.6	41.6	.	seed	41.6	.	.	PTI1995
Na	Oklahoma	TERB	field	resident	Millet	Monocot	*Panicumvirgatum*	6.5	.	20.3	69.05	.	seed	69.05	.	.	PTI1995
Na	Oklahoma	TERC	field	resident	Millet	Monocot	*Panicumvirgatum*	6.8	.	18.8	71.8	.	seed	71.8	.	.	PTI1995
Na	Oklahoma	GRID2	field	resident	Pigweed	Dicot	*Amaranthuspalmeri*	6.1	.	36.3	49.3	.	seed	81	.	.	PTI1995
Na	Oklahoma	GRID1	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	7.1	.	21.6	148	.	seed	94	.	.	PTI1995
Na	Oklahoma	GRID3	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.6	.	30.7	86.2	.	seed	16	.	.	PTI1995
Na	Oklahoma	TERA	field	resident	Ragweed	Dicot	*Ambrosiapsilostachya*	7	.	32.6	41.6	.	seed	41.6	.	.	PTI1995
Na	Oklahoma	TERC	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.8	.	18.8	71.8	.	seed	71.8	.	.	PTI1995
Na	Oklahoma	TRAP1	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.4	.	14.1	395	.	seed	395	.	.	PTI1995
Naphthlene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.017	.	leaf/stem	0.005	.	.	Kipopoulouetal.1999
Naphthlene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.017	.	leaf/stem	.	.	.	Kipopoulouetal.1999

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
Naphthlene	.	.	.	.	endive	.	.	.	.	.	0.017	.	leaf/stem	0.029	.	.	Kipopoulouetal.1999
Naphthlene	.	.	.	.	leek	.	.	.	.	.	0.017	.	leaf/stem	0.018	.	.	Kipopoulouetal.1999
Naphthlene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.017	.	leaf/stem	0.042	.	.	Kipopoulouetal.1999
Naphthlene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.017	.	root	.	.	.	Kipopoulouetal.1999
Naphthlene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.017	.	root	0.021	.	.	Kipopoulouetal.1999
Naphthlene	.	.	.	.	endive	.	.	.	.	.	0.017	.	root	.	.	.	Kipopoulouetal.1999
Naphthlene	.	.	.	.	leek	.	.	.	.	.	0.017	.	root	.	.	.	Kipopoulouetal.1999
Naphthlene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.017	.	root	.	.	.	Kipopoulouetal.1999
Naphthlene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.005246	.	leaf/stem	0.022	.	.	WildandJones1992
Naphthlene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.015996	.	leaf/stem	0.014	.	.	WildandJones1992
Naphthlene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.053406	.	leaf/stem	0.025	.	.	WildandJones1992
Naphthlene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.005246	.	root	0.0052	.	.	WildandJones1992
Naphthlene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.015996	.	root	0.0083	.	.	WildandJones1992
Naphthlene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.053406	.	root	0.0131	.	.	WildandJones1992
Ni	India	Polluted	field	resident	Rice	Monocot	*Oryzasativa*	.	.	.	39	.	leaf	26	.	.	Fazelietal.1998
Ni	India	Unpolluted	field	resident	Rice	Monocot	*Oryzasativa*	.	.	.	25	.	leaf	18	.	.	Fazelietal.1998
Ni	India	Polluted	field	resident	Rice	Monocot	*Oryzasativa*	.	.	.	39	.	seed	9	.	.	Fazelietal.1998
Ni	India	Unpolluted	field	resident	Rice	Monocot	*Oryzasativa*	.	.	.	25	.	seed	5	.	.	Fazelietal.1998
Ni	Reisenberg	100mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.7	4.9	21.0	78.7	.	leaf	3.62	.	.	Lombietal.1998
Ni	Untertiefenbach	100mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	83.67	.	leaf	1.71	.	.	Lombietal.1998
Ni	Weyersdorf	100mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	6.9	3.5	10.9	75.0	.	leaf	32.5	.	.	Lombietal.1998
Ni	Reisenberg	150mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.7	4.9	21.0	98.0	.	leaf	6.78	.	.	Lombietal.1998
Ni	Untertiefenbach	150mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	122.6	.	leaf	5.37	.	.	Lombietal.1998
Ni	Reisenberg	50mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.7	4.9	21.0	44.3	.	leaf	1.14	.	.	Lombietal.1998
Ni	Untertiefenbach	50mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	60.00	.	leaf	0.95	.	.	Lombietal.1998
Ni	Weyersdorf	50mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	6.9	3.5	10.9	50.0	.	leaf	2.96	.	.	Lombietal.1998
Ni	Reisenberg	Control	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.7	4.9	21.0	15.7	.	leaf	0.49	.	.	Lombietal.1998
Ni	Untertiefenbach	Control	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	35.33	.	leaf	0.4	.	.	Lombietal.1998
Ni	Weyersdorf	Control	lab	40day	sunflower	Dicot	*Helianthusannuus*	6.9	3.5	10.9	19.3	.	leaf	0.55	.	.	Lombietal.1998
Ni	Reisenberg	100mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.7	4.9	21.0	78.7	.	seed	6.01	.	.	Lombietal.1998
Ni	Untertiefenbach	100mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	83.67	.	seed	3.17	.	.	Lombietal.1998
Ni	Weyersdorf	100mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	6.9	3.5	10.9	75.0	.	seed	37.3	.	.	Lombietal.1998
Ni	Reisenberg	150mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.7	4.9	21.0	98.0	.	seed	3.08	.	.	Lombietal.1998
Ni	Untertiefenbach	150mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	122.6	.	seed	8.42	.	.	Lombietal.1998
Ni	Reisenberg	50mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.7	4.9	21.0	44.3	.	seed	1.56	.	.	Lombietal.1998
Ni	Untertiefenbach	50mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	60.00	.	seed	1.93	.	.	Lombietal.1998
Ni	Weyersdorf	50mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	6.9	3.5	10.9	50.0	.	seed	9.26	.	.	Lombietal.1998
Ni	Reisenberg	Control	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.7	4.9	21.0	15.7	.	seed	0.95	.	.	Lombietal.1998
Ni	Untertiefenbach	Control	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	35.33	.	seed	0.63	.	.	Lombietal.1998
Ni	Weyersdorf	Control	lab	40day	sunflower	Dicot	*Helianthusannuus*	6.9	3.5	10.9	19.3	.	seed	1.03	.	.	Lombietal.1998
Ni	Oklahoma	GRID3	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.6	.	30.7	10.2	.	seed	3	.	.	PTI1995
Ni	Oklahoma	GRID4	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	5.95	.	20.95	19.15	.	seed	4.3	.	.	PTI1995
Ni	Oklahoma	TRAP1	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.4	.	14.1	27.9	.	seed	27.9	.	.	PTI1995
Ni	Oklahoma	TRAP2	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6	.	31.7	20.2	.	seed	20.2	.	.	PTI1995
Ni	Oklahoma	TRAP2	field	resident	Greenbriar	Monocot	*Smilaxbona-nox*	6	.	31.7	20.2	.	seed	20.2	.	.	PTI1995
Ni	Oklahoma	GRID1	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7.1	.	21.6	26	.	seed	0.5	.	.	PTI1995
Ni	Oklahoma	GRID2	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.1	.	36.3	17.5	.	seed	0.4	.	.	PTI1995
Ni	Oklahoma	GRID3	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.6	.	30.7	10.2	.	seed	0.5	.	.	PTI1995
Ni	Oklahoma	TERA	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7	.	32.6	10.85	.	seed	10.85	.	.	PTI1995
Ni	Oklahoma	TERB	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.5	.	20.3	14.1	.	seed	14.1	.	.	PTI1995
Ni	Oklahoma	TERC	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.8	.	18.8	39.95	.	seed	39.95	.	.	PTI1995
Ni	Oklahoma	GRID1	field	resident	Millet	Monocot	*Panicumvirgatum*	7.1	.	21.6	26	.	seed	1.4	.	.	PTI1995
Ni	Oklahoma	GRID2	field	resident	Millet	Monocot	*Panicumvirgatum*	6.1	.	36.3	17.5	.	seed	0.6	.	.	PTI1995
Ni	Oklahoma	GRID4	field	resident	Millet	Monocot	*Panicumvirgatum*	5.95	.	20.95	19.15	.	seed	2.5	.	.	PTI1995

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
Ni	Oklahoma	TERA	field	resident	Millet	Monocot	*Panicumvirgatum*	7	.	32.6	10.85	.	seed	10.85	.	.	PTI1995
Ni	Oklahoma	TERB	field	resident	Millet	Monocot	*Panicumvirgatum*	6.5	.	20.3	14.1	.	seed	14.1	.	.	PTI1995
Ni	Oklahoma	TERC	field	resident	Millet	Monocot	*Panicumvirgatum*	6.8	.	18.8	39.95	.	seed	39.95	.	.	PTI1995
Ni	Oklahoma	GRID2	field	resident	Pigweed	Dicot	*Amaranthuspalmeri*	6.1	.	36.3	17.5	.	seed	2.9	.	.	PTI1995
Ni	Oklahoma	GRID1	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	7.1	.	21.6	26	.	seed	1.2	.	.	PTI1995
Ni	Oklahoma	GRID3	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.6	.	30.7	10.2	.	seed	5.3	.	.	PTI1995
Ni	Oklahoma	GRID4	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	5.95	.	20.95	19.15	.	seed	4.6	.	.	PTI1995
Ni	Oklahoma	TERA	field	resident	Ragweed	Dicot	*Ambrosiapsilostachya*	7	.	32.6	10.85	.	seed	10.85	.	.	PTI1995
Ni	Oklahoma	TERB	field	resident	Ragweed	Dicot	*Ambrosiapsilostachya*	6.5	.	20.3	14.1	.	seed	14.1	.	.	PTI1995
Ni	Oklahoma	TERC	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.8	.	18.8	39.95	.	seed	39.95	.	.	PTI1995
Ni	Oklahoma	TRAP1	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.4	.	14.1	27.9	.	seed	27.9	.	.	PTI1995
Ni	Oklahoma	TRAP1	field	resident	Ragweed	Dicot	*Ambrosiatrifida*	6.4	.	14.1	27.9	.	seed	27.9	.	.	PTI1995
Ni	Oklahoma	TRAP2	field	resident	Ragweed	Dicot	*Ambrosiatrifida*	6	.	31.7	20.2	.	seed	20.2	.	.	PTI1995
Ni	Canada	.	field	resident	Blueberry	Dicot	*Vacciniumangustifolium*	.	.	.	21	.	leaf	2.92	.	64	SheppardandEvenden1990
Ni	Turkey	1	field	resident	cherry	Dicot	*Prunussp.*	6.4	.	.	85	.	fuit	0.8	.	4	Yaman2000
Ni	Turkey	2	field	resident	cherry	Dicot	*Prunussp.*	6.3	.	.	27	.	fuit	0.6	.	4	Yaman2000
Ni	Turkey	3	field	resident	cherry	Dicot	*Prunussp.*	6.4	.	.	38	.	fuit	0.7	.	4	Yaman2000
Ni	Turkey	4	field	resident	cherry	Dicot	*Prunussp.*	6.3	.	.	15	.	fuit	0.6	.	4	Yaman2000
Ni	Turkey	4	field	resident	cherry	Dicot	*Prunussp.*	6.2	.	.	15	.	fuit	0.4	.	4	Yaman2000
Ni	Turkey	5	field	resident	cherry	Dicot	*Prunussp.*	6.1	.	.	18	.	fuit	0.5	.	4	Yaman2000
Ni	Turkey	6	field	resident	cherry	Dicot	*Prunussp.*	6.6	.	.	370	.	fuit	1.2	.	4	Yaman2000
Ni	Turkey	1	field	resident	mulberry	Dicot	*Morussp.*	6.4	.	.	90	.	fuit	1.4	.	4	Yaman2000
Ni	Turkey	3	field	resident	mulberry	Dicot	*Morussp.*	6.4	.	.	32	.	fuit	1.1	.	4	Yaman2000
Ni	Turkey	4	field	resident	mulberry	Dicot	*Morussp.*	6.4	.	.	13	.	fuit	1.2	.	4	Yaman2000
Ni	Turkey	5	field	resident	mulberry	Dicot	*Morussp.*	6.5	.	.	20	.	fuit	1.2	.	4	Yaman2000
Ni	Turkey	7	field	resident	pear	Dicot	*Pyrussp.*	6.5	.	.	18	.	fuit	1	.	4	Yaman2000
Ni	Turkey	1	field	resident	strawberry	Dicot	*Fragariasp.*	6.5	.	.	380	.	fuit	1.1	.	4	Yaman2000
Ni	Turkey	6	field	resident	strawberry	Dicot	*Fragariasp.*	6.6	.	.	215	.	fuit	0.9	.	4	Yaman2000
PAH	lab	mycorrhizal	lab	40days	Ryegrass	Monocot	*Loliumperenne*	.	2.9	.	1000	.	root	319.7	.	5	Binetetal.2000
PAH	lab	nonmycorrhizal	lab	40days	Ryegrass	Monocot	*Loliumperenne*	.	2.9	.	1000	.	root	164.80	.	5	Binetetal.2000
Pb	Pennsylvania	Palmerton	field	resident	acorns/berries	Dicot	mixedfruitsandacorns	5.9	12	14	41	.	fruit/seed	4	.	3	Beyeretal.1985
Pb	Pennsylvania	BakeOvenKnob	field	resident	acorns/berries	Dicot	mixedfruitsandacorns	5	23	19	150	.	fruit/seed	2.7	.	4	Beyeretal.1985
Pb	Maryland	1	field	resident	CommonReed	Monocot	*Phragmitesaustralis*	3	.	.	22	.	leaf	.	U	.	Beyeretal.1990
Pb	Delaware	2	field	resident	CommonReed	Monocot	*Phragmitesaustralis*	5.2	.	.	22	.	leaf	0.06	.	.	Beyeretal.1990
Pb	Maryland	3	field	resident	CommonReed	Monocot	*Phragmitesaustralis*	3.1	.	.	29	.	leaf	.	U	.	Beyeretal.1990
Pb	Pennsylvania	4	field	resident	CommonReed	Monocot	*Phragmitesaustralis*	*6.3*	.	.	92	.	leaf	0.29	.	.	Beyeretal.1990
Pb	Maryland	5	field	resident	CommonReed	Monocot	*Phragmitesaustralis*	3.6	.	.	530	.	leaf	0.06	.	.	Beyeretal.1990
Pb	India	Polluted	field	resident	Rice	Monocot	*Oryzasativa*	.	.	.	59	.	leaf	12	.	.	Fazelietal.1998
Pb	India	Unpolluted	field	resident	Rice	Monocot	*Oryzasativa*	.	.	.	42	.	leaf	7	.	.	Fazelietal.1998
Pb	India	Polluted	field	resident	Rice	Monocot	*Oryzasativa*	.	.	.	59	.	seed	9	.	.	Fazelietal.1998
Pb	India	Unpolluted	field	resident	Rice	Monocot	*Oryzasativa*	.	.	.	42	.	seed	4	.	.	Fazelietal.1998
Pb	Spain	1)Roadsideedge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.8	7	18	1453	.	wholeplant	5.23	.	.	Garciaetal.1996
Pb	Spain	2)Roadsideedge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.4	9.5	29	62	.	wholeplant	0.76	.	.	Garciaetal.1996
Pb	Spain	3)Roadsideedge	field	resident	Ryegrass	Monocot	*Loliumperenne*	8.1	4.2	15	727	.	wholeplant	7	.	.	Garciaetal.1996
Pb	Spain	4)Roadsideedge	field	resident	Ryegrass	Monocot	*Loliumperenne*	8	2.7	18	55	.	wholeplant	1.45	.	.	Garciaetal.1996
Pb	Spain	5)Roadsideedge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.6	10.6	27	327	.	wholeplant	1.26	.	.	Garciaetal.1996
Pb	Spain	6)Roadsideedge	field	resident	Ryegrass	Monocot	*Loliumperenne*	8.2	4.5	16	437	.	wholeplant	13.8	.	.	Garciaetal.1996
Pb	Spain	7)Roadsideedge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.9	7.4	19	451	.	wholeplant	6.76	.	.	Garciaetal.1996
Pb	Spain	8)Roadsideedge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.8	5	16	303	.	wholeplant	2.17	.	.	Garciaetal.1996
Pb	Spain	1)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.6	6.2	36	63	.	wholeplant	1	.	.	Garciaetal.1996
Pb	Spain	2)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	*Loliumperenne*	5.7	6.4	34	35	.	wholeplant	1.05	.	.	Garciaetal.1996
Pb	Spain	3)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7	10.6	48	98	.	wholeplant	2.12	.	.	Garciaetal.1996
Pb	Spain	4)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.7	3.1	27	46	.	wholeplant	1.5	.	.	Garciaetal.1996
Pb	Spain	5)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	*Loliumperenne*	6.9	24.6	51	83	.	wholeplant	1.36	.	.	Garciaetal.1996
Pb	Spain	6)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	*Loliumperenne*	6.9	6.4	30	136	.	wholeplant	1.3	.	.	Garciaetal.1996

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
Pb	Spain	7)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.7	8.5	26	161	.	w holeplant	2.2	.	.	Garciaetal.1996
Pb	Spain	8)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	*Loliumperenne*	7.9	5.2	24	87	.	w holeplant	0.94	.	.	Garciaetal.1996
Pb	Korea	miningsite	field	resident	Corn	Monocot	*Zeamays*	5.75	.	5.2	2700	.	seed	0.49	.	8	JungandThornton1996
Pb	Korea	after30days	field	resident	Rice	Monocot	*Oryzasativa*	5.5	.	13.2	84	.	leaf/stem	4.9	.	14	JungandThornton1997
Pb	Korea	after80days	field	resident	Rice	Monocot	*Oryzasativa*	5.5	.	11.3	85	.	leaf/stem	2.8	.	31	JungandThornton1997
Pb	Korea	after150days	field	resident	Rice	Monocot	*Oryzasativa*	5.3	.	11.3	114	.	seed	5.8	.	.	JungandThornton1997
Pb	Australia	.	field	resident	Waterlily	Dicot	*Nymphaeaviolacea*	.	.	.	.	.	leaf	.	.	5	Peterssonetal.1993
Pb	Oklahoma	GRID3	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.6	.	30.7	261	.	seed	0.47	J	.	PTI1995
Pb	Oklahoma	GRID4	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	5.95	.	20.95	281.5	.	seed	0.3	.	.	PTI1995
Pb	Oklahoma	TRAP1	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.4	.	14.1	485	.	seed	485	.	.	PTI1995
Pb	Oklahoma	TRAP2	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6	.	31.7	179	.	seed	179	.	.	PTI1995
Pb	Oklahoma	TRAP2	field	resident	Greenbriar	Monocot	*Smilaxbona-nox*	6	.	31.7	179	.	seed	179	.	.	PTI1995
Pb	Oklahoma	GRID1	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7.1	.	21.6	83.9	.	seed	12.4	.	.	PTI1995
Pb	Oklahoma	GRID2	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.1	.	36.3	435	.	seed	1.7	J	.	PTI1995
Pb	Oklahoma	GRID3	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.6	.	30.7	261	.	seed	1.1	J	.	PTI1995
Pb	Oklahoma	TERA	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7	.	32.6	32.05	.	seed	32.05	.	.	PTI1995
Pb	Oklahoma	TERB	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.5	.	20.3	63.9	.	seed	63.9	.	.	PTI1995
Pb	Oklahoma	TERC	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.8	.	18.8	33.8	.	seed	33.8	J	.	PTI1995
Pb	Oklahoma	GRID1	field	resident	Millet	Monocot	*Panicumvirgatum*	7.1	.	21.6	83.9	.	seed	11.7	.	.	PTI1995
Pb	Oklahoma	GRID2	field	resident	Millet	Monocot	*Panicumvirgatum*	6.1	.	36.3	435	.	seed	2.1	J	.	PTI1995
Pb	Oklahoma	GRID4	field	resident	Millet	Monocot	*Panicumvirgatum*	5.95	.	20.95	281.5	.	seed	0.25	.	.	PTI1995
Pb	Oklahoma	TERA	field	resident	Millet	Monocot	*Panicumvirgatum*	7	.	32.6	32.05	.	seed	32.05	.	.	PTI1995
Pb	Oklahoma	TERB	field	resident	Millet	Monocot	*Panicumvirgatum*	6.5	.	20.3	63.9	.	seed	63.9	.	.	PTI1995
Pb	Oklahoma	TERC	field	resident	Millet	Monocot	*Panicumvirgatum*	6.8	.	18.8	33.8	.	seed	33.8	J	.	PTI1995
Pb	Oklahoma	GRID2	field	resident	Pigw eed	Dicot	*Amaranthuspalmeri*	6.1	.	36.3	435	.	seed	1.4	J	.	PTI1995
Pb	Oklahoma	GRID1	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	7.1	.	21.6	83.9	.	seed	16.4	.	.	PTI1995
Pb	Oklahoma	GRID3	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	6.6	.	30.7	261	.	seed	0.82	J	.	PTI1995
Pb	Oklahoma	GRID4	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	5.95	.	20.95	281.5	.	seed	0.41	.	.	PTI1995
Pb	Oklahoma	TERA	field	resident	Ragw eed	Dicot	*Ambrosiapsilostachya*	7	.	32.6	32.05	.	seed	32.05	.	.	PTI1995
Pb	Oklahoma	TERB	field	resident	Ragw eed	Dicot	*Ambrosiapsilostachya*	6.5	.	20.3	63.9	.	seed	63.9	.	.	PTI1995
Pb	Oklahoma	TERC	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	6.8	.	18.8	33.8	.	seed	33.8	J	.	PTI1995
Pb	Oklahoma	TRAP1	field	resident	Ragw eed	Dicot	*Ambrosiaartemisiifolia*	6.4	.	14.1	485	.	seed	485	.	.	PTI1995
Pb	Oklahoma	TRAP1	field	resident	Ragw eed	Dicot	*Ambrosiatrifida*	6.4	.	14.1	485	.	seed	485	.	.	PTI1995
Pb	Oklahoma	TRAP2	field	resident	Ragw eed	Dicot	*Ambrosiatrifida*	6	.	31.7	179	.	seed	179	.	.	PTI1995
Pb	Wyoming	Reference	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	13.16	.	leaf	0.035	.	.	RamirezandRogers2000
Pb	Wyoming	Reference	field	resident	Brome	Monocot	*Bromussp.*	.	.	.	13.16	.	leaf	0.05	.	.	RamirezandRogers2000
Pb	Wyoming	StudyArea	field	resident	Dandelion	Dicot	*Taraxacumofficinale*	.	.	.	12.18	.	leaf	0.035	.	.	RamirezandRogers2000
Pb	Wyoming	Reference	field	resident	KentuckyBluegrass	Monocot	*PoaPratensis*	.	.	.	13.16	.	leaf	0.035	.	.	RamirezandRogers2000
Pb	Wyoming	StudyArea	field	resident	Pondw eed	Monocot	*Potamogetonsp*	.	.	.	0.00	.	leaf	2.02	.	.	RamirezandRogers2000
Pb	.	.	.	.	Annuals	Dicot	.	.	.	.	.	.	.	.	.	.	SheppardandEvenden1988
Pb	.	.	.	.	Annuals	Dicot	.	.	.	.	.	.	.	.	.	.	SheppardandEvenden1988
Pb	.	.	.	.	Annuals	Dicot	.	.	.	.	.	.	.	.	.	.	SheppardandEvenden1988
Pb	.	.	.	.	cereals	Monocot	.	.	.	.	.	.	.	.	.	.	SheppardandEvenden1988
Pb	.	.	.	.	cereals	Monocot	.	.	.	.	.	.	.	.	.	.	SheppardandEvenden1988
Pb	.	.	.	.	Forage	Monocot	.	.	.	.	.	.	.	.	.	.	SheppardandEvenden1988
Pb	.	.	.	.	Forage	Monocot	.	.	.	.	.	.	.	.	.	.	SheppardandEvenden1988
Pb	.	.	.	.	Forage	Monocot	.	.	.	.	.	.	.	.	.	.	SheppardandEvenden1988
Pb	.	.	.	.	Fruits	Dicot	.	.	.	.	.	.	.	.	.	.	SheppardandEvenden1988
Pb	.	.	.	.	Rootcrops	Dicot	.	.	.	.	.	.	.	.	.	.	SheppardandEvenden1988
Pb	.	.	.	.	Rootcrops	Dicot	.	.	.	.	.	.	.	.	.	.	SheppardandEvenden1988
Pb	.	.	.	.	shrubs	Dicot	.	.	.	.	.	.	.	.	.	.	SheppardandEvenden1988
Pb	.	.	.	.	trees	Dicot	.	.	.	.	.	.	.	.	.	.	SheppardandEvenden1988
Pb	.	.	.	.	trees	Dicot	.	.	.	.	.	.	.	.	.	.	SheppardandEvenden1988
Pb	.	.	.	.	trees	Dicot	.	.	.	.	.	.	.	.	.	.	SheppardandEvenden1988
Pb	.	.	.	.	Vegetables	Dicot	.	.	.	.	.	.	.	.	.	.	SheppardandEvenden1988

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
Pb	.	.	.	.	Vegetables	Dicot	.	.	.	.	.	.	.	.	.	.	SheppardandEvenden1988
Pb	Canada	.	field	resident	Blueberry	Dicot	*Vacciniumangustifolium*	.	.	.	26	.	leaf	1.34	.	58	SheppardandEvenden1990
Pb	Canada	within140kmofsudbury	field	resident	Blueberry	Dicot	*Vacciniumangustifolium*	4.34	.	.	32	.	leaf	1.95	.	14	SheppardandSheppard1991
Pb	Canada	NWOntarioManitoba	field	resident	Blueberry	Dicot	*Vacciniumangustifolium*	4.82	.	.	20	.	leaf	1.04	.	21	SheppardandSheppard1991
Pb	Canada	NoviaScotia	field	resident	Blueberry	Dicot	*Vacciniumangustifolium*	4.18	.	.	25	.	leaf	1.32	.	27	SheppardandSheppard1991
Pb	Canada	Sudbury	field	resident	Blueberry	Dicot	*Vacciniumangustifolium*	4.5	.	.	31	.	leaf	1.59	.	32	SheppardandSheppard1991
Pb	Colorado	.	field	resident	DevilsBitScabious	Dicot	*Succisapratensis*	6.48	.	.	7132	.	leaf	331.6	.	15	SteinbornandBreen1999
Pb	Colorado	.	field	resident	Germander	Dicot	*Teucriumscorodonica*	6.34	.	.	9498	.	leaf	1800	.	15	SteinbornandBreen1999
Pb	Colorado	.	field	resident	Primrose	Dicot	*Primulavulgaris*	6.8	.	.	9335	.	leaf	211	.	15	SteinbornandBreen1999
Pb	Colorado	.	field	resident	Moss	Bryophyte	*Rhytidiadelphusloreus*	7.13	.	.	6929	.	leaf/stem	5690	.	15	SteinbornandBreen1999
Pb	Colorado	.	field	resident	Stair-stepmoss	Bryophyte	*Hylocomiumsplendens*	6.54	.	.	8751	.	leaf/stem	5553.9	.	15	SteinbornandBreen1999
Phenanthrene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.0086	.	leaf/stem	0.018	.	.	Kipopoulouetal.1999
Phenanthrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0086	.	leaf/stem	.	.	.	Kipopoulouetal.1999
Phenanthrene	.	.	.	.	endive	.	.	.	.	.	0.0086	.	leaf/stem	0.043	.	.	Kipopoulouetal.1999
Phenanthrene	.	.	.	.	leek	.	.	.	.	.	0.0086	.	leaf/stem	0.033	.	.	Kipopoulouetal.1999
Phenanthrene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.0086	.	leaf/stem	0.058	.	.	Kipopoulouetal.1999
Phenanthrene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.0086	.	root	.	.	.	Kipopoulouetal.1999
Phenanthrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0086	.	root	0.027	.	.	Kipopoulouetal.1999
Phenanthrene	.	.	.	.	endive	.	.	.	.	.	0.0086	.	root	.	.	.	Kipopoulouetal.1999
Phenanthrene	.	.	.	.	leek	.	.	.	.	.	0.0086	.	root	.	.	.	Kipopoulouetal.1999
Phenanthrene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.0086	.	root	.	.	.	Kipopoulouetal.1999
Phenanthrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0183	.	leaf/stem	0.145	.	.	WildandJones1992
Phenanthrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0558	.	leaf/stem	0.133	.	.	WildandJones1992
Phenanthrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.1863	.	leaf/stem	0.129	.	.	WildandJones1992
Phenanthrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0183	.	root	0.0048	.	.	WildandJones1992
Phenanthrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0558	.	root	0.0055	.	.	WildandJones1992
Phenanthrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.1863	.	root	0.0042	.	.	WildandJones1992
Po	Australia	.	field	resident	Waterlily	Dicot	*Nymphaeaviolacea*	.	.	.	.	.	leaf	.	.	2	Petterssonetal.1993
Pyrene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.0054	.	leaf/stem	0.0039	.	.	Kipopoulouetal.1999
Pyrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0054	.	leaf/stem	.	.	.	Kipopoulouetal.1999
Pyrene	.	.	.	.	endive	.	.	.	.	.	0.0054	.	leaf/stem	0.013	.	.	Kipopoulouetal.1999
Pyrene	.	.	.	.	leek	.	.	.	.	.	0.0054	.	leaf/stem	0.01	.	.	Kipopoulouetal.1999
Pyrene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.0054	.	leaf/stem	0.02	.	.	Kipopoulouetal.1999
Pyrene	.	.	.	.	Cabbage	Dicot	*Brassicaoleracea*	.	.	.	0.0054	.	root	.	.	.	Kipopoulouetal.1999
Pyrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0054	.	root	0.0054	.	.	Kipopoulouetal.1999
Pyrene	.	.	.	.	endive	.	.	.	.	.	0.0054	.	root	.	.	.	Kipopoulouetal.1999
Pyrene	.	.	.	.	leek	.	.	.	.	.	0.0054	.	root	.	.	.	Kipopoulouetal.1999
Pyrene	.	.	.	.	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.0054	.	root	.	.	.	Kipopoulouetal.1999
Pyrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0122	.	leaf/stem	0.036	.	.	WildandJones1992
Pyrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0372	.	leaf/stem	0.026	.	.	WildandJones1992
Pyrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.1242	.	leaf/stem	0.024	.	.	WildandJones1992
Pyrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0122	.	root	0.001	.	.	WildandJones1992
Pyrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.0372	.	root	0.0028	.	.	WildandJones1992
Pyrene	.	.	.	.	Carrot	Dicot	*Daucascarota*	.	.	.	0.1242	.	root	0.0028	.	.	WildandJones1992
Ra	Australia	.	field	resident	Waterlily	Dicot	*Nymphaeaviolacea*	.	.	.	.	.	leaf	.	.	5	Petterssonetal.1993
RDX	Iowa	8	field	resident	arrowhead	Dicot	*Saggitariacalycina*	.	.	.	1160	.	leaf/stem	1	U	.	Schneider_et_al_1995
RDX	Iowa	20	field	resident	blacklocust	Dicot	Robiniapseudo-acacia	.	.	.	114	.	leaf/stem	38.6	.	.	Schneider_et_al_1995
RDX	Iowa	111	field	resident	blacklocust	Dicot	*Robiniapseudo-acacia*	.	.	.	1.6	.	leaf/stem	17.2	.	.	Schneider_et_al_1995
RDX	Iowa	144-2	field	resident	blacklocust	Dicot	*Robiniapseudo-acacia*	.	.	.	1	U	leaf/stem	1	U	.	Schneider_et_al_1995
RDX	Iowa	112-1	field	resident	milkweed	Dicot	*Asclepiassyriaca*	.	.	.	46.1	.	leaf/stem	88.6	.	.	Schneider_et_al_1995
RDX	Iowa	9	field	resident	Corn	Monocot	*Zeamays*	.	.	.	1.4	.	leaf/stem	1	U	.	Schneider_et_al_1995
RDX	Iowa	10	field	resident	Corn	Monocot	*Zeamays*	.	.	.	1	U	leaf/stem	1	U	.	Schneider_et_al_1995
RDX	Iowa	11	field	resident	Corn	Monocot	*Zeamays*	.	.	.	1	U	leaf/stem	1	U	.	Schneider_et_al_1995
RDX	Iowa	101	field	resident	Corn	Monocot	*Zeamays*	.	.	.	1	U	leaf/stem	1	U	.	Schneider_et_al_1995
RDX	Iowa	102	field	resident	Corn	Monocot	*Zeamays*	.	.	.	1	U	leaf/stem	1	U	.	Schneider_et_al_1995
RDX	Iowa	103	field	resident	Corn	Monocot	*Zeamays*	.	.	.	1	U	leaf/stem	1	U	.	Schneider_et_al_1995
RDX	Iowa	14	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	1	U	leaf/stem	1	U	.	Schneider_et_al_1995
RDX	Iowa	18	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	57.1	.	leaf/stem	35	.	.	Schneider_et_al_1995

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
RDX	Iowa	109	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	1100	.	leaf/stem	37.9	.	.	Schneider_et_al_1995
RDX	Iowa	112-2	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	46.1	.	leaf/stem	5.64	.	.	Schneider_et_al_1995
RDX	Iowa	114-1	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	1	U	leaf/stem	1	U	.	Schneider_et_al_1995
RDX	Iowa	19-2	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	9	.	leaf/stem	23.6	.	.	Schneider_et_al_1995
RDX	Iowa	5	field	resident	Pigweed	Dicot	*Amaranthussp.*	.	.	.	59.7	.	leaf/stem	3.6	.	.	Schneider_et_al_1995
RDX	Iowa	6	field	resident	Pigweed	Dicot	*Amaranthussp.*	.	.	.	6.5	.	leaf/stem	1	U	.	Schneider_et_al_1995
RDX	Iowa	106	field	resident	Pigweed	Dicot	*Amaranthussp.*	.	.	.	3.8	.	leaf/stem	10.7	.	.	Schneider_et_al_1995
RDX	Iowa	21	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	.	.	.	702	.	leaf/stem	73.9	.	.	Schneider_et_al_1995
RDX	Iowa	107	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	.	.	.	3.7	.	leaf/stem	1	U	.	Schneider_et_al_1995
RDX	Iowa	108	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	.	.	.	166	.	leaf/stem	33.4	.	.	Schneider_et_al_1995
RDX	Iowa	113	field	resident	redcedar	Gymnosperm	*Juniperusviginiana*	.	.	.	16.8	.	leaf/stem	42	.	.	Schneider_et_al_1995
RDX	Iowa	12	field	resident	reedcanarygrass	Monocot	Phalarisarundinacea	.	.	.	19.4	.	leaf/stem	10.1	.	.	Schneider_et_al_1995
RDX	Iowa	17	field	resident	reedcanarygrass	Monocot	Phalarisarundinacea	.	.	.	1.4	.	leaf/stem	1	U	.	Schneider_et_al_1995
RDX	Iowa	110	field	resident	reedcanarygrass	Monocot	*Phalarisarundinacea*	.	.	.	43.3	.	leaf/stem	1	U	.	Schneider_et_al_1995
RDX	Iowa	19-1	field	resident	reedcanarygrass	Monocot	Phalarisarundinacea	.	.	.	9	.	leaf/stem	1	U	.	Schneider_et_al_1995
RDX	Iowa	1	field	resident	smartweed	Dicot	*Polygonumsp.*	.	.	.	2.5	.	leaf/stem	51.2	.	.	Schneider_et_al_1995
RDX	Iowa	104	field	resident	smartweed	Dicot	*Polygonumsp.*	.	.	.	3.2	.	leaf/stem	5.03	.	.	Schneider_et_al_1995
RDX	Iowa	4	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	5010	.	leaf/stem	72.1	.	.	Schneider_et_al_1995
RDX	Iowa	105	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	1800	.	leaf/stem	41.5	.	.	Schneider_et_al_1995
RDX	Iowa	112-3	field	resident	sunflower	Dicot	*Helianthusnutallii*	.	.	.	46.1	.	leaf/stem	8.61	.	.	Schneider_et_al_1995
RDX	Iowa	8	field	resident	arrowhead	Dicot	*Saggitariacalycina*	.	.	.	1160	.	root	7.4	.	.	Schneider_et_al_1995
RDX	Iowa	20	field	resident	blacklocust	Dicot	Robiniapseudo-acacia	.	.	.	114	.	root	1	U	.	Schneider_et_al_1995
RDX	Iowa	111	field	resident	blacklocust	Dicot	*Robiniapseudo-acacia*	.	.	.	1.6	.	root	5.77	.	.	Schneider_et_al_1995
RDX	Iowa	112-1	field	resident	milkweed	Dicot	*Asclepiassyriaca*	.	.	.	46.1	.	root	8.2	.	.	Schneider_et_al_1995
RDX	Iowa	101	field	resident	Corn	Monocot	*Zeamays*	.	.	.	1	U	root	1	U	.	Schneider_et_al_1995
RDX	Iowa	102	field	resident	Corn	Monocot	*Zeamays*	.	.	.	1	U	root	1	U	.	Schneider_et_al_1995
RDX	Iowa	103	field	resident	Corn	Monocot	*Zeamays*	.	.	.	1	U	root	1	U	.	Schneider_et_al_1995
RDX	Iowa	14	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	1	U	root	263	.	.	Schneider_et_al_1995
RDX	Iowa	18	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	57.1	.	root	904	.	.	Schneider_et_al_1995
RDX	Iowa	109	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	1100	.	root	2.3	.	.	Schneider_et_al_1995
RDX	Iowa	112-2	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	46.1	.	root	1	U	.	Schneider_et_al_1995
RDX	Iowa	5	field	resident	Pigweed	Dicot	*Amaranthussp.*	.	.	.	59.7	.	root	1	U	.	Schneider_et_al_1995
RDX	Iowa	6	field	resident	Pigweed	Dicot	*Amaranthussp.*	.	.	.	6.5	.	root	1	U	.	Schneider_et_al_1995
RDX	Iowa	106	field	resident	Pigweed	Dicot	*Amaranthussp.*	.	.	.	3.8	.	root	20.2	.	.	Schneider_et_al_1995
RDX	Iowa	21	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	.	.	.	702	.	root	31.5	.	.	Schneider_et_al_1995
RDX	Iowa	107	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	.	.	.	3.7	.	root	1	U	.	Schneider_et_al_1995
RDX	Iowa	108	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	.	.	.	166	.	root	17.7	.	.	Schneider_et_al_1995
RDX	Iowa	110	field	resident	reedcanarygrass	Monocot	*Phalarisarundinacea*	.	.	.	43.3	.	root	1	U	.	Schneider_et_al_1995
RDX	Iowa	1	field	resident	smartweed	Dicot	*Polygonumsp.*	.	.	.	2.5	.	root	1	U	.	Schneider_et_al_1995
RDX	Iowa	104	field	resident	smartweed	Dicot	*Polygonumsp.*	.	.	.	3.2	.	root	4.09	.	.	Schneider_et_al_1995
RDX	Iowa	4	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	5010	.	root	1	U	.	Schneider_et_al_1995
RDX	Iowa	105	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	1800	.	root	15.8	.	.	Schneider_et_al_1995
RDX	Iowa	112-3	field	resident	sunflower	Dicot	*Helianthusnutallii*	.	.	.	46.1	.	root	4.28	.	.	Schneider_et_al_1995
RDX	Iowa	101	field	resident	Corn	Monocot	*Zeamays*	.	.	.	1	U	seed	1	U	.	Schneider_et_al_1995
RDX	Iowa	102	field	resident	Corn	Monocot	*Zeamays*	.	.	.	1	U	seed	1	U	.	Schneider_et_al_1995
RDX	Iowa	103	field	resident	Corn	Monocot	*Zeamays*	.	.	.	1	U	seed	1	U	.	Schneider_et_al_1995
RDX	Lab	17.4	lab	2days	EasternCottonwood	Dicot	*PopulusDeltoidesssp.nigra*	.	.	.	.	.	leaf	470	.	3	Thompsonetal.1999
RDX	Lab	7.9	lab	6days	EasternCottonwood	Dicot	*PopulusDeltoidesssp.nigra*	.	.	.	.	.	leaf	354	.	3	Thompsonetal.1999
RDX	Lab	26	lab	7days	EasternCottonwood	Dicot	*PopulusDeltoidesssp.nigra*	.	.	.	.	.	leaf	723	.	3	Thompsonetal.1999
RDX	Lab	17.4	lab	2days	EasternCottonwood	Dicot	*PopulusDeltoidesssp.nigra*	.	.	.	.	.	root	877	.	3	Thompsonetal.1999
RDX	Lab	7.9	lab	6days	EasternCottonwood	Dicot	*PopulusDeltoidesssp.nigra*	.	.	.	.	.	root	694	.	3	Thompsonetal.1999
RDX	Lab	26	lab	7days	EasternCottonwood	Dicot	*PopulusDeltoidesssp.nigra*	.	.	.	.	.	root	1494	.	3	Thompsonetal.1999
RDX	Lab	17.4	lab	2days	EasternCottonwood	Dicot	*PopulusDeltoidesssp.nigra*	.	.	.	.	.	stem	50	.	3	Thompsonetal.1999
RDX	Lab	7.9	lab	6days	EasternCottonwood	Dicot	*PopulusDeltoidesssp.nigra*	.	.	.	.	.	stem	46	.	3	Thompsonetal.1999

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
RDX	Lab	26	lab	7days	EasternCottonwood	Dicot	*PopulusDeltoidesssp.nigra*	.	.	.	.	.	stem	121	.	3	Thompsonetal.1999
Sb	.	.	.	.	.	.	*Achilleaageratum*	.	.	.	27.74	.	leaf	6.09	.	.	Baronietal.2000
Sb	.	.	.	.	.	.	*Achilleaageratum*	.	.	.	202.8	.	leaf	8.75	.	.	Baronietal.2000
Sb	.	.	.	.	.	.	*Achilleaageratum*	.	.	.	15112.94	.	leaf	121.35	.	.	Baronietal.2000
Sb	.	.	.	.	.	.	*Achilleaageratum*	.	.	.	4317.21	.	leaf	74.27	.	.	Baronietal.2000
Sb	.	.	.	.	.	.	*Achilleaageratum*	.	.	.	9197.5	.	leaf	1367.29	.	.	Baronietal.2000
Sb	.	.	.	.	.	.	*Achilleaageratum*	.	.	.	7364.27	.	leaf	329.51	.	.	Baronietal.2000
Sb	.	.	.	.	.	.	*Silenevulgaris*	.	.	.	15112.94	.	leaf	51.77	.	.	Baronietal.2000
Sb	.	.	.	.	.	.	*Silenevulgaris*	.	.	.	4317.21	.	leaf	19.45	.	.	Baronietal.2000
Sb	.	.	.	.	.	.	*Silenevulgaris*	.	.	.	9197.5	.	leaf	853.75	.	.	Baronietal.2000
Sb	.	.	.	.	.	.	*Silenevulgaris*	.	.	.	7364.27	.	leaf	349.62	.	.	Baronietal.2000
Sb	.	.	.	.	plantain	Dicot	*Plantagolanceolata*	.	.	.	202.8	.	leaf	28.45	.	.	Baronietal.2000
Sb	.	.	.	.	plantain	Dicot	*Plantagolanceolata*	.	.	.	15112.94	.	leaf	53.64	.	.	Baronietal.2000
Sb	.	.	.	.	plantain	Dicot	*Plantagolanceolata*	.	.	.	4317.21	.	leaf	33.58	.	.	Baronietal.2000
Sb	.	.	.	.	plantain	Dicot	*Plantagolanceolata*	.	.	.	9197.5	.	leaf	569.34	.	.	Baronietal.2000
Sb	.	.	.	.	plantain	Dicot	*Plantagolanceolata*	.	.	.	7364.27	.	leaf	274.63	.	.	Baronietal.2000
Sb	Oklahoma	GRID3	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.6	.	.	4.4	.	leaf/stem	0.05	.	.	PTI1995
Sb	.	.	.	.	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.6	.	.	4.4	.	leaf/stem	0.04	.	.	PTI1995
Sb	Oklahoma	GRID3	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.6	.	30.7	4.4	.	seed	0.04	.	.	PTI1995
Sb	Canada	.	field	resident	Blueberry	Dicot	*Vacciniumangustifolium*	.	.	.	5.9	.	leaf	0.6	U	.	SheppardandEvenden1990
Se	California	Kesterson	field	resident	BirdfootTrefoil	Dicot	*Lotuscorniculatus*	.	.	.	0.6	.	leaf/stem	0.32	.	.	Banuelosetal.1999
Se	California	Kesterson	field	resident	Mustard	Dicot	*Brassicajuncea*	.	.	.	0.6	.	leaf/stem	1	.	.	Banuelosetal.1999
Se	California	Kesterson	field	resident	Rose-Mallow	Dicot	*Hibiscuscanabinus*	.	.	.	0.6	.	leaf/stem	0.5	.	.	Banuelosetal.1999
Se	California	Kesterson	field	resident	TallFescue	Monocot	*Festucaarundinacea*	.	.	.	0.6	.	leaf/stem	0.15	.	.	Banuelosetal.1999
Se	California	Kesterson	field	resident	BirdfootTrefoil	Dicot	*Lotuscorniculatus*	.	.	.	0.6	.	root	0.13	.	.	Banuelosetal.1999
Se	California	Kesterson	field	resident	Mustard	Dicot	*Brassicajuncea*	.	.	.	0.6	.	root	0.8	.	.	Banuelosetal.1999
Se	California	Kesterson	field	resident	Rose-Mallow	Dicot	*Hibiscuscanabinus*	.	.	.	0.6	.	root	0.5	.	.	Banuelosetal.1999
Se	California	Kesterson	field	resident	TallFescue	Monocot	*Festucaarundinacea*	.	.	.	0.6	.	root	0.11	.	.	Banuelosetal.1999
Se	Maryland	1	field	resident	CommonReed	Monocot	*Phragmitesaustralis*	3	.	.	0.66	.	leaf	.	U	.	Beyeretal.1990
Se	Delaware	2	field	resident	CommonReed	Monocot	*Phragmitesaustralis*	5.2	.	.	0.38	.	leaf	0.12	.	.	Beyeretal.1990
Se	Maryland	3	field	resident	CommonReed	Monocot	*Phragmitesaustralis*	3.1	.	.	0.89	.	leaf	.	U	.	Beyeretal.1990
Se	Pennsylvania	4	field	resident	CommonReed	Monocot	*Phragmitesaustralis*	*6.3*	.	.	0.75	.	leaf	0.08	.	.	Beyeretal.1990
Se	Maryland	5	field	resident	CommonReed	Monocot	*Phragmitesaustralis*	3.6	.	.	4.8	.	leaf	0.41	.	.	Beyeretal.1990
Se	Total	.	lab	maturity	Squash	Dicot	*Cucurbitasp.*	6.5	.	.	0.3366	.	fruit	0.0111	.	3	Cappon1987
Se	Total	.	lab	maturity	cucumber	Dicot	*Cucumissativus*	6.5	.	.	0.3366	.	fruit	0.0091	.	4	Cappon1987
Se	Total	.	lab	maturity	Pepper	Dicot	*Capsicumannuum*	6.5	.	.	0.3366	.	fruit	0.0114	.	8	Cappon1987
Se	Total	.	lab	maturity	tomato	Dicot	*Lycopersiconesculentum*	6.5	.	.	0.3366	.	fruit	0.0566	.	8	Cappon1987
Se	Total	.	lab	maturity	Broccoli	Dicot	*Brassicaoleracea*	6.5	.	.	0.3366	.	leaf	0.0347	.	8	Cappon1987
Se	Total	.	lab	maturity	Cabbage	Dicot	*Brassicaoleracea*	6.5	.	.	0.3366	.	leaf	0.0091	.	8	Cappon1987
Se	Total	.	lab	maturity	Lettuce	Dicot	*Lactucasativa*	6.5	.	.	0.3366	.	Leaf	0.057	.	12	Cappon1987
Se	Total	.	lab	maturity	beet	Dicot	*Betavulgaris*	6.5	.	.	0.3366	.	leaf	0.0402	.	18	Cappon1987
Se	Total	.	lab	maturity	Turnip	Dicot	*Brassicarapa*	6.5	.	.	0.3366	.	root	0.017	.	18	Cappon1987
Se	Total	.	lab	maturity	spinach	Dicot	*Spinaciaoleracea*	6.5	.	.	0.3366	.	leaf	0.0709	.	24	Cappon1987
Se	Total	.	lab	maturity	Onion	Monocot	*Alliumcepa*	6.5	.	.	0.3366	.	stem	0.1479	.	24	Cappon1987
Se	Total	.	lab	maturity	beet	Dicot	*Betasp.*	6.5	.	.	0.3366	.	root	0.0201	.	36	Cappon1987
Se	Total	.	lab	maturity	Radish	Dicot	*Raphanussativus*	6.5	.	.	0.3366	.	root	0.0592	.	36	Cappon1987
Se	Total	.	lab	maturity	Lettuce	Dicot	*Lactucasativa*	6.5	.	.	0.3366	.	leaf	0.0697	.	40	Cappon1987
Se	Total	.	lab	maturity	Bean	Dicot	*Phaselousvulgaris*	6.5	.	.	0.3366	.	seed	0.0213	.	40	Cappon1987
Se	Total	.	lab	maturity	Carrot	Dicot	*Daucascarota*	6.5	.	.	0.3366	.	root	0.0234	.	48	Cappon1987
Se	Texas	Minesoil1	lab	3week	bermudagrass	Monocot	*Cynodendactylon*	8.1	.	.	2.81	.	leaf/stem	9.92	.	.	Hossneretal.1992
Se	Texas	Minesoil2	lab	3week	bermudagrass	Monocot	*Cynodendactylon*	8.0	.	.	5.57	.	leaf/stem	5.19	.	.	Hossneretal.1992
Se	Texas	Wilco	lab	3week	bermudagrass	Monocot	*Cynodendactylon*	7.2	.	.	0.11	.	leaf/stem	0.46	.	.	Hossneretal.1992
Se	Texas	Minesoil1	lab	4week	bermudagrass	Monocot	*Cynodendactylon*	8.1	.	.	2.81	.	leaf/stem	11.95	.	.	Hossneretal.1992
Se	Texas	Minesoil2	lab	4week	bermudagrass	Monocot	*Cynodendactylon*	8.0	.	.	5.57	.	leaf/stem	2.34	.	.	Hossneretal.1992
Se	Texas	Wilco	lab	4week	bermudagrass	Monocot	*Cynodendactylon*	7.2	.	.	0.11	.	leaf/stem	1.03	.	.	Hossneretal.1992

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
Se	Texas	Minesoil1	lab	3week	buffalograss	Monocot	*Buchloedactyloides*	8.1	.	.	2.81	.	leaf/stem	13.26	.	.	Hossneretal.1992
Se	Texas	Minesoil2	lab	3week	buffalograss	Monocot	*Buchloedactyloides*	8.0	.	.	5.57	.	leaf/stem	14.75	.	.	Hossneretal.1992
Se	Texas	Wilco	lab	3week	buffalograss	Monocot	*Buchloedactyloides*	7.2	.	.	0.11	.	leaf/stem	1.13	.	.	Hossneretal.1992
Se	Texas	Minesoil1	lab	4week	buffalograss	Monocot	*Buchloedactyloides*	8.1	.	.	2.81	.	leaf/stem	5.02	.	.	Hossneretal.1992
Se	Texas	Minesoil2	lab	4week	buffalograss	Monocot	*Buchloedactyloides*	8.0	.	.	5.57	.	leaf/stem	2.75	.	.	Hossneretal.1992
Se	Texas	Wilco	lab	4week	buffalograss	Monocot	*Buchloedactyloides*	7.2	.	.	0.11	.	leaf/stem	0.80	.	.	Hossneretal.1992
Se	Texas	Minesoil1	lab	3week	kleingrass	Monocot	*Panicumcoloratum*	8.1	.	.	2.81	.	leaf/stem	9.46	.	.	Hossneretal.1992
Se	Texas	Minesoil2	lab	3week	kleingrass	Monocot	*Panicumcoloratum*	8.0	.	.	5.57	.	leaf/stem	5.33	.	.	Hossneretal.1992
Se	Texas	Wilco	lab	3week	kleingrass	Monocot	*Panicumcoloratum*	7.2	.	.	0.11	.	leaf/stem	0.89	.	.	Hossneretal.1992
Se	Texas	Minesoil1	lab	4week	kleingrass	Monocot	*Panicumcoloratum*	8.1	.	.	2.81	.	leaf/stem	28.13	.	.	Hossneretal.1992
Se	Texas	Minesoil2	lab	4week	kleingrass	Monocot	*Panicumcoloratum*	8.0	.	.	5.57	.	leaf/stem	2.14	.	.	Hossneretal.1992
Se	Texas	Wilco	lab	4week	kleingrass	Monocot	*Panicumcoloratum*	7.2	.	.	0.11	.	leaf/stem	1.18	.	.	Hossneretal.1992
Se	Texas	Minesoil1	lab	3week	littlebluestem	Monocot	*Schizachyriumscoparium*	8.1	.	.	2.81	.	leaf/stem	8.47	.	.	Hossneretal.1992
Se	Texas	Minesoil2	lab	3week	littlebluestem	Monocot	*Schizachyriumscoparium*	8.0	.	.	5.57	.	leaf/stem	35.59	.	.	Hossneretal.1992
Se	Texas	Wilco	lab	3week	littlebluestem	Monocot	*Schizachyriumscoparium*	7.2	.	.	0.11	.	leaf/stem	0.89	.	.	Hossneretal.1992
Se	Texas	Minesoil1	lab	4week	littlebluestem	Monocot	*Schizachyriumscoparium*	8.1	.	.	2.81	.	leaf/stem	66.84	.	.	Hossneretal.1992
Se	Texas	Minesoil2	lab	4week	littlebluestem	Monocot	*Schizachyriumscoparium*	8.0	.	.	5.57	.	leaf/stem	5.79	.	.	Hossneretal.1992
Se	Texas	Wilco	lab	4week	littlebluestem	Monocot	*Schizachyriumscoparium*	7.2	.	.	0.11	.	leaf/stem	0.61	.	.	Hossneretal.1992
Se	Texas	Minesoil1	lab	3week	Millet	Monocot	*Panicumvirgatum*	8.1	.	.	2.81	.	leaf/stem	3.74	.	.	Hossneretal.1992
Se	Texas	Minesoil2	lab	3week	Millet	Monocot	*Panicumvirgatum*	8.0	.	.	5.57	.	leaf/stem	15.06	.	.	Hossneretal.1992
Se	Texas	Wilco	lab	3week	Millet	Monocot	*Panicumvirgatum*	7.2	.	.	0.11	.	leaf/stem	1.79	.	.	Hossneretal.1992
Se	Texas	Minesoil1	lab	4week	Millet	Monocot	*Panicumvirgatum*	8.1	.	.	2.81	.	leaf/stem	22.72	.	.	Hossneretal.1992
Se	Texas	Minesoil2	lab	4week	Millet	Monocot	*Panicumvirgatum*	8.0	.	.	5.57	.	leaf/stem	4.70	.	.	Hossneretal.1992
Se	Texas	Wilco	lab	4week	Millet	Monocot	*Panicumvirgatum*	7.2	.	.	0.11	.	leaf/stem	0.90	.	.	Hossneretal.1992
Se	Texas	Minesoil1	lab	3week	plainsbristlegrass	Monocot	*Setarialeucopila*	8.1	.	.	2.81	.	leaf/stem	4.78	.	.	Hossneretal.1992
Se	Texas	Minesoil2	lab	3week	plainsbristlegrass	Monocot	*Setarialeucopila*	8.0	.	.	5.57	.	leaf/stem	27.64	.	.	Hossneretal.1992
Se	Texas	Wilco	lab	3week	plainsbristlegrass	Monocot	*Setarialeucopila*	7.2	.	.	0.11	.	leaf/stem	0.80	.	.	Hossneretal.1992
Se	Texas	Minesoil1	lab	4week	plainsbristlegrass	Monocot	*Setarialeucopila*	8.1	.	.	2.81	.	leaf/stem	69.88	.	.	Hossneretal.1992
Se	Texas	Minesoil2	lab	4week	plainsbristlegrass	Monocot	*Setarialeucopila*	8.0	.	.	5.57	.	leaf/stem	2.35	.	.	Hossneretal.1992
Se	Texas	Wilco	lab	4week	plainsbristlegrass	Monocot	*Setarialeucopila*	7.2	.	.	0.11	.	leaf/stem	1.38	.	.	Hossneretal.1992
Se	Texas	Minesoil1	lab	3week	sanddropseed	Monocot	*Sporobuluscryptandrus*	8.1	.	.	2.81	.	leaf/stem	4.21	.	.	Hossneretal.1992
Se	Texas	Minesoil2	lab	3week	sanddropseed	Monocot	*Sporobuluscryptandrus*	8.0	.	.	5.57	.	leaf/stem	9.61	.	.	Hossneretal.1992
Se	Texas	Wilco	lab	3week	sanddropseed	Monocot	*Sporobuluscryptandrus*	7.2	.	.	0.11	.	leaf/stem	0.89	.	.	Hossneretal.1992
Se	Texas	Minesoil1	lab	4week	sanddropseed	Monocot	*Sporobuluscryptandrus*	8.1	.	.	2.81	.	leaf/stem	52.29	.	.	Hossneretal.1992
Se	Texas	Minesoil2	lab	4week	sanddropseed	Monocot	*Sporobuluscryptandrus*	8.0	.	.	5.57	.	leaf/stem	5.08	.	.	Hossneretal.1992
Se	Texas	Wilco	lab	4week	sanddropseed	Monocot	*Sporobuluscryptandrus*	7.2	.	.	0.11	.	leaf/stem	0.42	.	.	Hossneretal.1992
Se	Texas	Minesoil1	lab	3week	sandlovegrass	Monocot	*Eragrostistrichodes*	8.1	.	.	2.81	.	leaf/stem	3.07	.	.	Hossneretal.1992
Se	Texas	Minesoil2	lab	3week	sandlovegrass	Monocot	*Eragrostistrichodes*	8.0	.	.	5.57	.	leaf/stem	34.71	.	.	Hossneretal.1992
Se	Texas	Wilco	lab	3week	sandlovegrass	Monocot	*Eragrostistrichodes*	7.2	.	.	0.11	.	leaf/stem	1.06	.	.	Hossneretal.1992
Se	Texas	Minesoil1	lab	4week	sandlovegrass	Monocot	*Eragrostistrichodes*	8.1	.	.	2.81	.	leaf/stem	52.19	.	.	Hossneretal.1992
Se	Texas	Minesoil2	lab	4week	sandlovegrass	Monocot	*Eragrostistrichodes*	8.0	.	.	5.57	.	leaf/stem	.	.	.	Hossneretal.1992
Se	Texas	Wilco	lab	4week	sandlovegrass	Monocot	*Eragrostistrichodes*	7.2	.	.	0.11	.	leaf/stem	1.60	.	.	Hossneretal.1992
Se	Texas	Minesoil1	lab	3week	sideoatsgrammagrass	Monocot	*Boutelouacurtipendula*	8.1	.	.	2.81	.	leaf/stem	0.90	.	.	Hossneretal.1992
Se	Texas	Minesoil2	lab	3week	sideoatsgrammagrass	Monocot	*Boutelouacurtipendula*	8.0	.	.	5.57	.	leaf/stem	0.25	.	.	Hossneretal.1992
Se	Texas	Wilco	lab	3week	sideoatsgrammagrass	Monocot	*Boutelouacurtipendula*	7.2	.	.	0.11	.	leaf/stem	0.57	.	.	Hossneretal.1992
Se	Texas	Minesoil1	lab	4week	sideoatsgrammagrass	Monocot	*Boutelouacurtipendula*	8.1	.	.	2.81	.	leaf/stem	44.75	.	.	Hossneretal.1992
Se	Texas	Minesoil2	lab	4week	sideoatsgrammagrass	Monocot	*Boutelouacurtipendula*	8.0	.	.	5.57	.	leaf/stem	3.08	.	.	Hossneretal.1992
Se	Texas	Wilco	lab	4week	sideoatsgrammagrass	Monocot	*Boutelouacurtipendula*	7.2	.	.	0.11	.	leaf/stem	1.14	.	.	Hossneretal.1992
Se	Texas	Minesoil1	lab	3week	vinemesquite	Monocot	*Panicumobtusam*	8.1	.	.	2.81	.	leaf/stem	6.48	.	.	Hossneretal.1992
Se	Texas	Minesoil2	lab	3week	vinemesquite	Monocot	*Panicumobtusam*	8.0	.	.	5.57	.	leaf/stem	2.63	.	.	Hossneretal.1992
Se	Texas	Wilco	lab	3week	vinemesquite	Monocot	*Panicumobtusam*	7.2	.	.	0.11	.	leaf/stem	0.73	.	.	Hossneretal.1992
Se	Texas	Minesoil1	lab	4week	vinemesquite	Monocot	*Panicumobtusam*	8.1	.	.	2.81	.	leaf/stem	66.61	.	.	Hossneretal.1992
Se	Texas	Minesoil2	lab	4week	vinemesquite	Monocot	*Panicumobtusam*	8.0	.	.	5.57	.	leaf/stem	8.42	.	.	Hossneretal.1992
Se	Texas	Wilco	lab	4week	vinemesquite	Monocot	*Panicumobtusam*	7.2	.	.	0.11	.	leaf/stem	0.91	.	.	Hossneretal.1992
Se	Chile	Casablanca(CB)Reference	field	resident	Grape	Dicot	*Vitussp.*	.	.	.	0.1	.	fruit	.	U	.	Pinochetetal.1999
Se	Chile	Catemu(C-2)	field	resident	Grape	Dicot	*Vitussp.*	.	.	.	0.22	.	fruit	.	U	.	Pinochetetal.1999
Se	Chile	LaGreda(P-1)	field	resident	Grape	Dicot	*Vitussp.*	.	.	.	0.49	.	fruit	0.06	.	.	Pinochetetal.1999
Se	Chile	Maitenes(P-2)	field	resident	Grape	Dicot	*Vitussp.*	.	.	.	0.31	.	fruit	0.035	.	.	Pinochetetal.1999

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
Se	Chile	Nogales(P-4)	field	resident	Grape	Dicot	*Vitussp.*	.	.	.	0.37	.	fruit	0.008	.	.	Pinochetetal.1999
Se	Chile	Panquehue(C-4)	field	resident	Grape	Dicot	*Vitussp.*	.	.	.	0.15	.	fruit	0.017	.	.	Pinochetetal.1999
Se	Chile	Puchuncavi(P-3)	field	resident	Grape	Dicot	*Vitussp.*	.	.	.	0.4	.	fruit	0.02	.	.	Pinochetetal.1999
Se	Chile	SanJose(C-2)	field	resident	Grape	Dicot	*Vitussp.*	.	.	.	0.2	.	fruit	.	U	.	Pinochetetal.1999
Se	Chile	StaMargaritam(C-3)	field	resident	Grape	Dicot	*Vitussp.*	.	.	.	0.23	.	fruit	0.035	.	.	Pinochetetal.1999
Se	Chile	Casablanca(CB)Reference	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	0.1	.	fruit	0.009	.	.	Pinochetetal.1999
Se	Chile	Catemu(C-2)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	0.22	.	fruit	0.015	.	.	Pinochetetal.1999
Se	Chile	LaGreda(P-1)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	0.49	.	fruit	0.043	.	.	Pinochetetal.1999
Se	Chile	Maitenes(P-2)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	0.31	.	fruit	0.024	.	.	Pinochetetal.1999
Se	Chile	Nogales(P-4)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	0.37	.	fruit	0.015	.	.	Pinochetetal.1999
Se	Chile	Panquehue(C-4)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	0.15	.	fruit	0.031	.	.	Pinochetetal.1999
Se	Chile	PPuchuncavi(P-3)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	0.4	.	fruit	0.02	.	.	Pinochetetal.1999
Se	Chile	SanJose(C-2)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	0.2	.	fruit	0.014	.	.	Pinochetetal.1999
Se	Chile	StaMargaritam(C-3)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	0.23	.	fruit	0.04	.	.	Pinochetetal.1999
Se	Chile	LaGreda(P-1)	field	resident	plantain	Dicot	*Plantagolanceolata*	.	.	.	0.49	.	fruit/leaf	0.15	.	.	Pinochetetal.1999
Se	Chile	Panquehue(C-4)	field	resident	Cabbage	Dicot	*Brassicaoleraceae*	.	.	.	0.15	.	leaf	.	U	.	Pinochetetal.1999
Se	Chile	Catemu(C-2)	field	resident	Grass	Monocot	*Poaannoa*	.	.	.	0.22	.	leaf	0.021	.	.	Pinochetetal.1999
Se	Chile	Chagres(C-1b)	field	resident	Grass	Monocot	*Poaannoa*	.	.	.	0.22	.	leaf	0.047	.	.	Pinochetetal.1999
Se	Chile	LaGreda(P-1)	field	resident	Grass	Monocot	*Poaannoa*	.	.	.	0.49	.	leaf	0.16	.	.	Pinochetetal.1999
Se	Chile	Maitenes(P-2)	field	resident	Grass	Monocot	*Poaannoa*	.	.	.	0.31	.	leaf	0.21	.	.	Pinochetetal.1999
Se	Chile	Nogales(P-4)	field	resident	Grass	Monocot	*Poaannoa*	.	.	.	0.37	.	leaf	0.04	.	.	Pinochetetal.1999
Se	Chile	Panquehue(C-4)	field	resident	Grass	Monocot	*Poaannoa*	.	.	.	0.15	.	leaf	0.042	.	.	Pinochetetal.1999
Se	Chile	PPuchuncavi(P-3)	field	resident	Grass	Monocot	*Poaannoa*	.	.	.	0.4	.	leaf	0.3	.	.	Pinochetetal.1999
Se	Chile	SanJose(C-2)	field	resident	Grass	Monocot	*Poaannoa*	.	.	.	0.2	.	leaf	0.031	.	.	Pinochetetal.1999
Se	Chile	StaMargaritam(C-3)	field	resident	Grass	Monocot	*Poaannoa*	.	.	.	0.23	.	leaf	0.028	.	.	Pinochetetal.1999
Se	Chile	Campiche(P-2b)	field	resident	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.28	.	leaf	0.07	.	.	Pinochetetal.1999
Se	Chile	Puchuncavi(P-3)	field	resident	Lettuce	Dicot	*Lactucasativa*	.	.	.	0.4	.	leaf	0.06	.	.	Pinochetetal.1999
Se	Chile	Casablanca(CB)Reference	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	0.1	.	leaf	0.03	.	.	Pinochetetal.1999
Se	Chile	Catemu(C-2)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	0.22	.	leaf	0.18	.	.	Pinochetetal.1999
Se	Chile	LaGreda(P-1)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	0.49	.	leaf	0.34	.	.	Pinochetetal.1999
Se	Chile	Maitenes(P-2)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	0.31	.	leaf	0.61	.	.	Pinochetetal.1999
Se	Chile	Nogales(P-4)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	0.37	.	leaf	0.18	.	.	Pinochetetal.1999
Se	Chile	Panquehue(C-4)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	0.15	.	leaf	0.26	.	.	Pinochetetal.1999
Se	Chile	PPuchuncavi(P-3)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	0.4	.	leaf	0.1	.	.	Pinochetetal.1999
Se	Chile	SanJose(C-2)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	0.2	.	leaf	0.15	.	.	Pinochetetal.1999
Se	Chile	StaMargaritam(C-3)	field	resident	Quince	Dicot	*Cydoniaoblonga*	.	.	.	0.23	.	leaf	0.15	.	.	Pinochetetal.1999
Se	Chile	Campiche(P-2b)	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	0.28	.	leaf/stem	0.23	.	.	Pinochetetal.1999
Se	Chile	Casablanca(CB)Reference	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	0.1	.	leaf/stem	0.08	.	.	Pinochetetal.1999
Se	Chile	Catemu(C-2)	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	0.22	.	leaf/stem	0.15	.	.	Pinochetetal.1999
Se	Chile	LaGreda(P-1)	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	0.49	.	leaf/stem	0.28	.	.	Pinochetetal.1999
Se	Chile	Maitenes(P-2)	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	0.31	.	leaf/stem	0.3	.	.	Pinochetetal.1999
Se	Chile	Nogales(P-4)	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	0.37	.	leaf/stem	0.22	.	.	Pinochetetal.1999
Se	Chile	Panquehue(C-4)	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	0.15	.	leaf/stem	0.23	.	.	Pinochetetal.1999
Se	Chile	PPuchuncavi(P-3)	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	0.4	.	leaf/stem	0.37	.	.	Pinochetetal.1999
Se	Chile	SanJose(C-2)	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	0.2	.	leaf/stem	0.1	.	.	Pinochetetal.1999
Se	Chile	StaMargaritam(C-3)	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	0.23	.	leaf/stem	0.12	.	.	Pinochetetal.1999
Se	Chile	Catemu(C-2)	field	resident	Celery	Dicot	*Apiumgraveolens*	.	.	.	0.22	.	leaf/stem	0.06	.	.	Pinochetetal.1999
Se	Chile	Puchuncavi(P-3)	field	resident	Celery	Dicot	*Apiumgraveolens*	.	.	.	0.4	.	leaf/stem	0.05	.	.	Pinochetetal.1999
Se	Chile	Puchuncavi(P-3)	field	resident	Yuyo	Dicot	*Brassicarapa*	.	.	.	0.4	.	seed/stem	0.39	.	.	Pinochetetal.1999
Se	Chile	Campiche(P-2b)	field	resident	Onion	Monocot	*Alliumcepa*	.	.	.	0.28	.	stem	0.06	.	.	Pinochetetal.1999
Se	Oklahoma	TRAP1	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.4	.	14.1	19.2	.	seed	19.2	.	.	PTI1995
Se	Oklahoma	TRAP1	field	resident	Ragweed	Dicot	*Ambrosiatrifida*	6.4	.	14.1	19.2	.	seed	19.2	.	.	PTI1995
Se	Wyoming	Reference	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	0.62	.	leaf	0.41	.	.	RamirezandRogers2000
Se	Wyoming	Reference	field	resident	Brome	Monocot	*Bromussp.*	.	.	.	0.62	.	leaf	0.45	.	.	RamirezandRogers2000
Se	Wyoming	StudyArea	field	resident	Brome	Monocot	*Bromussp.*	.	.	.	32.66	.	leaf	8.16	.	.	RamirezandRogers2000

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
Se	Wyoming	StudyArea	field	resident	Dandelion	Dicot	*Taraxacumofficinale*	.	.	.	3.09	.	leaf	25	.	.	RamirezandRogers2000
Se	Wyoming	StudyArea	field	resident	FoxtailBarley	Dicot	*Hordiumjubatum*	.	.	.	3.09	.	leaf	14.11	.	.	RamirezandRogers2000
Se	Wyoming	Reference	field	resident	KentuckyBluegrass	Monocot	*PoaPratensis*	.	.	.	0.62	.	leaf	0.3	.	.	RamirezandRogers2000
Se	Wyoming	StudyArea	field	resident	Pondweed	Monocot	*Potamogetonsp*	.	.	.	0.16	.	leaf	464.78	.	.	RamirezandRogers2000
Se	California	Kesterson	field	248days	Grass	Monocot	*Elytrigiapontica*	7.8	.	14	20.5	.	leaf/stem	11.9	.	.	Retanaetal.1993
Se	California	Kesterson	field	248days	Grass	Monocot	*Oryzopsishymenoides*	7.8	.	14	20.5	.	leaf/stem	19.2	.	.	Retanaetal.1993
Se	California	Kesterson	field	248days	Grass	Monocot	*Sporobolusairoides*	7.8	.	14	20.5	.	leaf/stem	8.7	.	.	Retanaetal.1993
Se	California	Kesterson	field	248days	Seaccumulator	Dicot	*Astragalusbisulcatus*	7.8	.	14	20.5	.	leaf/stem	595	.	.	Retanaetal.1993
Se	California	Kesterson	field	248days	Seaccumulator	Dicot	*Astragalusracemosus*	7.8	.	14	20.5	.	leaf/stem	670	.	.	Retanaetal.1993
Se	California	Kesterson	field	248days	Grass	Monocot	*Elytrigiapontica*	7.8	.	14	20.5	.	root	21.4	.	.	Retanaetal.1993
Se	California	Kesterson	field	248days	Grass	Monocot	*Oryzopsishymenoides*	7.8	.	14	20.5	.	root	53.6	.	.	Retanaetal.1993
Se	California	Kesterson	field	248days	Grass	Monocot	*Sporobolusairoides*	7.8	.	14	20.5	.	root	15.3	.	.	Retanaetal.1993
Se	California	Kesterson	field	248days	Seaccumulator	Dicot	*Astragalusbisulcatus*	7.8	.	14	20.5	.	root	318	.	.	Retanaetal.1993
Se	California	Kesterson	field	248days	Seaccumulator	Dicot	*Astragalusracemosus*	7.8	.	14	20.5	.	root	312	.	.	Retanaetal.1993
Th	Australia	.	field	resident	Waterlily	Dicot	*Nymphaeaviolacea*	.	.	.	.	.	leaf	.	.	5	Petterssonetal.1993
Th	Australia	.	field	resident	Waterlily	Dicot	*Nymphaeaviolacea*	.	.	.	.	.	leaf	.	.	5	Petterssonetal.1993
Th	Australia	.	field	resident	Waterlily	Dicot	*Nymphaeaviolacea*	.	.	.	.	.	leaf	.	.	5	Petterssonetal.1993
Th	Canada	.	field	resident	Blueberry	Dicot	*Vacciniumangustifolium*	.	.	.	4.1	.	leaf	0.01	U	.	SheppardandEvenden1990
Ti	Canada	.	field	resident	Blueberry	Dicot	*Vacciniumangustifolium*	.	.	.	2200	.	leaf	4.0	.	64	SheppardandEvenden1990
TNT	lab	0	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	leaf	1	.	.	PalazzoandLeggett1986
TNT	lab	5	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	leaf	4	.	.	PalazzoandLeggett1986
TNT	lab	10	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	leaf	4	.	.	PalazzoandLeggett1986
TNT	lab	20	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	leaf	13	.	.	PalazzoandLeggett1986
TNT	lab	0	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	1	.	.	PalazzoandLeggett1986
TNT	lab	5	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	20	.	.	PalazzoandLeggett1986
TNT	lab	10	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	70	.	.	PalazzoandLeggett1986
TNT	lab	20	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	95	.	.	PalazzoandLeggett1986
TNT	lab	0	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	11	.	.	PalazzoandLeggett1986
TNT	lab	5	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	112	.	.	PalazzoandLeggett1986
TNT	lab	10	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	298	.	.	PalazzoandLeggett1986
TNT	lab	20	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	714	.	.	PalazzoandLeggett1986
TNT	lab	0	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	0	.	.	PalazzoandLeggett1986
TNT	lab	5	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	11	.	.	PalazzoandLeggett1986
TNT	lab	10	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	27	.	.	PalazzoandLeggett1986
TNT	lab	20	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	69	.	.	PalazzoandLeggett1986
TNT	Iowa	8	field	resident	arrowhead	Dicot	*Saggitariacalycina*	.	.	.	10500	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	20	field	resident	blacklocust	Dicot	Robiniapseudo-acacia	.	.	.	13.8	.	leaf/stem	4.4	.	.	Schneider_et_al_1995
TNT	Iowa	111	field	resident	blacklocust	Dicot	*Robiniapseudo-acacia*	.	.	.	7.6	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	144-2	field	resident	blacklocust	Dicot	*Robiniapseudo-acacia*	.	.	.	0.8	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	112-1	field	resident	milkweed	Dicot	*Asclepiassyriaca*	.	.	.	2.7	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	9	field	resident	Corn	Monocot	*Zeamays*	.	.	.	9.9	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	10	field	resident	Corn	Monocot	*Zeamays*	.	.	.	4.2	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	11	field	resident	Corn	Monocot	*Zeamays*	.	.	.	1.1	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	101	field	resident	Corn	Monocot	*Zeamays*	.	.	.	26.5	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	102	field	resident	Corn	Monocot	*Zeamays*	.	.	.	5.5	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	103	field	resident	Corn	Monocot	*Zeamays*	.	.	.	2.3	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	14	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	0.5	U	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	18	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	5.1	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	109	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	33700	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	112-1	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	2.7	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	114-1	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	0.8	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	19-2	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	0.9	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	5	field	resident	Pigweed	Dicot	*Amaranthussp.*	.	.	.	526	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	6	field	resident	Pigweed	Dicot	*Amaranthussp.*	.	.	.	47.6	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	106	field	resident	Pigweed	Dicot	*Amaranthussp.*	.	.	.	22.6	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	21	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	.	.	.	15900	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	107	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	.	.	.	143	.	leaf/stem	0.5	U	.	Schneider_et_al_1995

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
TNT	Iowa	108	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	.	.	.	4660	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	113	field	resident	redcedar	Gymnosperm	*Juniperusviginiana*	.	.	.	4.7	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	12	field	resident	reedcanarygrass	Monocot	Phalarisarundinacea	.	.	.	4.5	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	17	field	resident	reedcanarygrass	Monocot	Phalarisarundinacea	.	.	.	1.8	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	110	field	resident	reedcanarygrass	Monocot	*Phalarisarundinacea*	.	.	.	15.9	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	19-1	field	resident	reedcanarygrass	Monocot	Phalarisarundinacea	.	.	.	0.9	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	1	field	resident	smartweed	Dicot	*Polygonumsp.*	.	.	.	3610	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	104	field	resident	smartweed	Dicot	*Polygonumsp.*	.	.	.	32.2	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	4	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	42700	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	105	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	11000	.	leaf/stem	0.76	.	.	Schneider_et_al_1995
TNT	Iowa	112-3	field	resident	sunflower	Dicot	*Helianthusnutallii*	.	.	.	2.7	.	leaf/stem	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	8	field	resident	arrowhead	Dicot	*Saggitariacalycina*	.	.	.	10500	.	root	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	20	field	resident	blacklocust	Dicot	Robiniapseudo-acacia	.	.	.	13.8	.	root	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	111	field	resident	blacklocust	Dicot	*Robiniapseudo-acacia*	.	.	.	7.6	.	root	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	112-1	field	resident	milkweed	Dicot	*Asclepiassyriaca*	.	.	.	2.7	.	root	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	101	field	resident	Corn	Monocot	*Zeamays*	.	.	.	26.5	.	root	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	102	field	resident	Corn	Monocot	*Zeamays*	.	.	.	26.5	.	root	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	103	field	resident	Corn	Monocot	*Zeamays*	.	.	.	2.3	.	root	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	14	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	0.5	U	root	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	18	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	5.1	.	root	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	109	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	33700	.	root	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	112-2	field	resident	goldenrod	Dicot	*Solidagocanadensis*	.	.	.	2.7	.	root	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	5	field	resident	Pigweed	Dicot	*Amaranthussp.*	.	.	.	526	.	root	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	6	field	resident	Pigweed	Dicot	*Amaranthussp.*	.	.	.	47.6	.	root	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	106	field	resident	Pigweed	Dicot	*Amaranthussp.*	.	.	.	22.6	.	root	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	21	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	.	.	.	15900	.	root	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	107	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	.	.	.	143	.	root	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	108	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	.	.	.	4660	.	root	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	110	field	resident	reedcanarygrass	Monocot	*Phalarisarundinacea*	.	.	.	15.9	.	root	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	1	field	resident	smartweed	Dicot	*Polygonumsp.*	.	.	.	3610	.	root	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	104	field	resident	smartweed	Dicot	*Polygonumsp.*	.	.	.	32.2	.	root	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	4	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	42700	.	root	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	105	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	11000	.	root	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	112-3	field	resident	sunflower	Dicot	*Helianthusnutallii*	.	.	.	2.7	.	root	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	101	field	resident	Corn	Monocot	*Zeamays*	.	.	.	26.5	.	seed	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	102	field	resident	Corn	Monocot	*Zeamays*	.	.	.	26.5	.	seed	0.5	U	.	Schneider_et_al_1995
TNT	Iowa	103	field	resident	Corn	Monocot	*Zeamays*	.	.	.	2.3	.	seed	0.5	U	.	Schneider_et_al_1995
TNT	Illinois	9	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	5840	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	13	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	5340	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	14	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	3350	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	4	field	resident	bluevervain	Monocot	*Verbenahastata*	.	.	.	1.5	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	10	field	resident	chicory	Dicot	*Cichoriumintybus*	.	.	.	3360	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	14	field	resident	chicory	Dicot	*Cichoriumintybus*	.	.	.	3350	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	15	field	resident	chicory	Dicot	*Cichoriumintybus*	.	.	.	202	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	5	field	resident	groundcherry	Monocot	*Physalisheterophylla*	.	.	.	1.6	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	1	field	resident	milkweed	Dicot	*Asciepiassyriaca*	.	.	.	0.08	U	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	3	field	resident	milkweed	Dicot	*Asciepiassyriaca*	.	.	.	1	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	8	field	resident	milkweed	Dicot	*Asciepiassyriaca*	.	.	.	278	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	14	field	resident	milkweed	Dicot	*Asciepiassyriaca*	.	.	.	3350	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	2	field	resident	commonteasel	Dicot	*Dipsacussylvestris*	.	.	.	0.08	U	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	6	field	resident	commonteasel	Dicot	*Dipsacussylvestris*	.	.	.	6260	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	7	field	resident	commonteasel	Dicot	*Dipsacussylvestris*	.	.	.	492	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	12	field	resident	commonteasel	Dicot	*Dipsacussylvestris*	.	.	.	39350	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	3	field	resident	falseboneset	Dicot	*Kuhniaeupatorioides*	.	.	.	1	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	10	field	resident	QueenAnne'slace	Dicot	*Daucuscarota*	.	.	.	3360	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	15	field	resident	QueenAnne'slace	Dicot	*Daucuscarota*	.	.	.	202	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	1	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	0.08	U	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	2	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	0.08	U	leaf/stem	0.08	U	.	Zellmer_et_al_1995

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
TNT	Illinois	3	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	1	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	4	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	1.5	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	5	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	1.6	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	6	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	6260	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	7	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	492	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	8	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	278	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	9	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	5840	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	11	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	3410	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	12	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	39350	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	13	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	5340	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	14	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	3350	.	leaf/stem	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	13	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	5340	.	root	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	14	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	3350	.	root	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	4	field	resident	bluevervain	Monocot	*Verbenahastata*	.	.	.	1.5	.	root	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	10	field	resident	chicory	Dicot	*Cichoriumintybus*	.	.	.	3360	.	root	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	14	field	resident	chicory	Dicot	*Cichoriumintybus*	.	.	.	3350	.	root	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	15	field	resident	chicory	Dicot	*Cichoriumintybus*	.	.	.	202	.	root	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	5	field	resident	groundcherry	Monocot	*Physalisheterophylla*	.	.	.	1.6	.	root	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	1	field	resident	milkw eed	Dicot	*Asciepiassyriaca*	.	.	.	0.08	U	root	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	3	field	resident	milkw eed	Dicot	*Asciepiassyriaca*	.	.	.	1	.	root	0.6	.	.	Zellmer_et_al_1995
TNT	Illinois	8	field	resident	milkw eed	Dicot	*Asciepiassyriaca*	.	.	.	278	.	root	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	14	field	resident	milkw eed	Dicot	*Asciepiassyriaca*	.	.	.	3350	.	root	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	2	field	resident	commonteasel	Dicot	*Dipsacussylvestris*	.	.	.	0.08	U	root	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	6	field	resident	commonteasel	Dicot	*Dipsacussylvestris*	.	.	.	6260	.	root	0.15	.	.	Zellmer_et_al_1995
TNT	Illinois	7	field	resident	commonteasel	Dicot	*Dipsacussylvestris*	.	.	.	492	.	root	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	12	field	resident	commonteasel	Dicot	*Dipsacussylvestris*	.	.	.	39350	.	root	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	3	field	resident	falseboneset	Dicot	*Kuhniaeupatorioides*	.	.	.	0.08	U	root	0.13	.	.	Zellmer_et_al_1995
TNT	Illinois	10	field	resident	QueenAnne'slace	Dicot	*Daucuscarota*	.	.	.	3360	.	root	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	15	field	resident	QueenAnne'slace	Dicot	*Daucuscarota*	.	.	.	202	.	root	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	1	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	0.08	U	root	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	2	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	0.08	U	root	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	3	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	1	.	root	4.5	.	.	Zellmer_et_al_1995
TNT	Illinois	4	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	1.5	.	root	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	5	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	1.6	.	root	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	6	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	6260	.	root	2.33	.	.	Zellmer_et_al_1995
TNT	Illinois	7	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	492	.	root	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	8	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	278	.	root	0.29	.	.	Zellmer_et_al_1995
TNT	Illinois	9	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	5840	.	root	5.85	.	.	Zellmer_et_al_1995
TNT	Illinois	11	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	3410	.	root	0.08	U	.	Zellmer_et_al_1995
TNT	Illinois	12	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	39350	.	root	3.85	.	.	Zellmer_et_al_1995
TNT	Illinois	13	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	5340	.	root	0.86	.	.	Zellmer_et_al_1995
TNT	Illinois	14	field	resident	smoothbromegrass	Monocot	*Bromusinermis*	.	.	.	3350	.	root	0.08	U	.	Zellmer_et_al_1995
TNT+metabolites	lab	0	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	leaf	3	.	.	PalazzoandLeggett1986
TNT+metabolites	lab	5	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	leaf	46	.	.	PalazzoandLeggett1986
TNT+metabolites	lab	10	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	leaf	127	.	.	PalazzoandLeggett1986
TNT+metabolites	lab	20	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	leaf	243	.	.	PalazzoandLeggett1986
TNT+metabolites	lab	0	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	7	.	.	PalazzoandLeggett1986
TNT+metabolites	lab	5	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	274	.	.	PalazzoandLeggett1986
TNT+metabolites	lab	10	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	451	.	.	PalazzoandLeggett1986
TNT+metabolites	lab	20	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	795	.	.	PalazzoandLeggett1986
TNT+metabolites	lab	0	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	36	.	.	PalazzoandLeggett1986
TNT+metabolites	lab	5	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	2082	.	.	PalazzoandLeggett1986
TNT+metabolites	lab	10	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	2692	.	.	PalazzoandLeggett1986
TNT+metabolites	lab	20	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	3508	.	.	PalazzoandLeggett1986
TNT+metabolites	lab	0	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	0	.	.	PalazzoandLeggett1986
TNT+metabolites	lab	5	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	97	.	.	PalazzoandLeggett1986
TNT+metabolites	lab	10	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	437	.	.	PalazzoandLeggett1986
TNT+metabolites	lab	20	lab	42days	yellow nutsedge	Monocot	*Cyperusesculentus*	.	.	.	.	.	root	384	.	.	PalazzoandLeggett1986
U	New Mexico	LAC	field	6months	zucchini	Dicot	*Cucurbitapepo*	7.1	1.2	4.8	2.15	.	fruit	0.0028	.	.	Fresquezetal.1998
U	New Mexico	RBG	field	6months	zucchini	Dicot	*Cucurbitapepo*	.	.	.	2.26	.	fruit	0.0066	.	.	Fresquezetal.1998

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
U	New Mexico	LAC	field	6months	Bean	Dicot	*Phaselousvulgaris*	7.1	1.2	4.8	2.15	.	seed	0.001	.	.	Fresquezetal.1998
U	New Mexico	RBG	field	6months	Bean	Dicot	*Phaselousvulgaris*	.	.	.	2.26	.	seed	0.0025	.	.	Fresquezetal.1998
U	New Mexico	LAC	field	6months	Corn	Monocot	*Zeamays*	7.1	1.2	4.8	2.15	.	seed	0.0021	.	.	Fresquezetal.1998
U	New Mexico	RBG	field	6months	Corn	Monocot	*Zeamays*	.	.	.	2.26	.	seed	0.001	.	.	Fresquezetal.1998
U	New Mexico	LAC	field	6months	Bean	Dicot	*Phaselousvulgaris*	7.1	1.2	4.8	2.15	.	leaf/stem	0.06	.	.	Fresquezetal.1998
U	New Mexico	RBG	field	6months	Bean	Dicot	*Phaselousvulgaris*	.	.	.	2.26	.	leaf/stem	0.002	.	.	Fresquezetal.1998
U	New Mexico	LAC	field	6months	Corn	Monocot	*Zeamays*	7.1	1.2	4.8	2.15	.	leaf/stem	0.0045	.	.	Fresquezetal.1998
U	New Mexico	RBG	field	6months	Corn	Monocot	*Zeamays*	.	.	.	2.26	.	leaf/stem	0.0109	.	.	Fresquezetal.1998
U	New Mexico	LAC	field	6months	zucchini	Dicot	*Cucurbitapepo*	7.1	1.2	4.8	2.15	.	leaf/stem	0.0129	.	.	Fresquezetal.1998
U	New Mexico	RBG	field	6months	zucchini	Dicot	*Cucurbitapepo*	.	.	.	2.26	.	leaf/stem	0.0096	.	.	Fresquezetal.1998
U	Ontario	PortHope-Background	field	resident	beet	Dicot	*Betasp.*	.	.	.	2	.	fruit	0.0009	U	.	Mortvedt1994
U	Ontario	PortHope-Contaminated	field	resident	beet	Dicot	*Betasp.*	.	.	.	33	.	fruit	0.0009	U	.	Mortvedt1994
U	Ontario	PortHope-Background	field	resident	cucumber	Dicot	*Cucumissativus*	.	.	.	2	.	fruit	0.0009	U	.	Mortvedt1994
U	Ontario	PortHope-Contaminated	field	resident	cucumber	Dicot	*Cucumissativus*	.	.	.	33	.	fruit	0.0018	.	.	Mortvedt1994
U	Ontario	PortHope-Background	field	resident	tomato	Dicot	*Lycopersiconesculentum*	.	.	.	2	.	fruit	0.0035	.	.	Mortvedt1994
U	Ontario	PortHope-Contaminated	field	resident	tomato	Dicot	*Lycopersiconesculentum*	.	.	.	33	.	fruit	0.0009	U	.	Mortvedt1994
U	Ontario	PortHope-Background	field	resident	beet	Dicot	*Betasp.*	.	.	.	2	.	leaf	0.0547	.	.	Mortvedt1994
U	Ontario	PortHope-Background	field	resident	beet	Dicot	*Betavulgaris*	.	.	.	2	.	leaf	0.0013	U	.	Mortvedt1994
U	Ontario	PortHope-Contaminated	field	resident	beet	Dicot	*Betavulgaris*	.	.	.	33	.	leaf	0.0353	.	.	Mortvedt1994
U	Ontario	PortHope-Contaminated	field	resident	beet	Dicot	*Betavulgaris*	.	.	.	33	.	leaf	0.0013	U	.	Mortvedt1994
U	Alabama	AuburnUniversity	field	resident	Corn	Monocot	*Zeamays*	.	.	.	1.01	.	leaf	0.01	.	.	Mortvedt1994
U	Alabama	AuburnUniversity	field	resident	soybean	Dicot	*Glycinemax*	.	.	.	1.01	.	leaf	0.05	.	.	Mortvedt1994
U	Missouri	SanbornPlots	field	resident	timothy	Monocot	*Phleumpratense*	.	.	.	1.7	.	leaf/stem	0.04	.	.	Mortvedt1994
U	Ontario	PortHope-Background	field	resident	Bean	Dicot	*Phaselousvulgaris*	.	.	.	2	.	seed	0.0003	.	.	Mortvedt1994
U	Ontario	PortHope-Contaminated	field	resident	Bean	Dicot	*Phaselousvulgaris*	.	.	.	33	.	seed	0.002	.	.	Mortvedt1994
U	Alabama	AuburnUniversity	field	resident	Corn	Monocot	*Zeamays*	.	.	.	1.01	.	seed	0.01	.	.	Mortvedt1994
U	Illinois	Morrow Field	field	resident	Corn	Monocot	*Zeamays*	.	.	.	1.4	.	seed	0.01	.	.	Mortvedt1994
U	Missouri	SanbornPlots	field	resident	Corn	Monocot	*Zeamays*	.	.	.	1.7	.	seed	0.01	.	.	Mortvedt1994
U	Alabama	AuburnUniversity	field	resident	soybean	Dicot	*Glycinemax*	.	.	.	1.01	.	seed	0.01	.	.	Mortvedt1994
U	Oklahoma	MagruderPlots	field	resident	wheat	Monocot	*Triticumaestivum*	.	.	.	1.3	.	seed	0.01	.	.	Mortvedt1994
U	Missouri	SanbornPlots	field	resident	wheat	Monocot	*Triticumaestivum*	.	.	.	1.7	.	seed	0.001	J	.	Mortvedt1994
U	Ontario	PortHope-Background	field	resident	Carrot	Dicot	*Daucascarota*	.	.	.	2	.	stem	0.0009	U	.	Mortvedt1994
U	Ontario	PortHope-Contaminated	field	resident	Carrot	Dicot	*Daucascarota*	.	.	.	33	.	stem	0.2261	.	.	Mortvedt1994
U	Ontario	PortHope-Background	field	resident	Onion	Monocot	*Alliumsp.*	.	.	.	2	.	stem	0.0009	U	.	Mortvedt1994
U	Ontario	PortHope-Contaminated	field	resident	Onion	Monocot	*Alliumsp.*	.	.	.	33	.	stem	0.0652	.	.	Mortvedt1994
U	Oklahoma	MagruderPlots	field	resident	wheat	Monocot	*Triticumaestivum*	.	.	.	1.3	.	stem	0.02	.	.	Mortvedt1994
U	Ontario	PortHope-Background	field	resident	potato	Dicot	*Solanumtuberosum*	.	.	.	2	.	root	0.007	.	.	Mortvedt1994
U	Ontario	PortHope-Contaminated	field	resident	potato	Dicot	*Solanumtuberosum*	.	.	.	33	.	root	0.0026	.	.	Mortvedt1994
U	Australia	.	field	resident	Waterlily	Dicot	*Nymphaeaviolacea*	.	.	.	.	.	leaf	.	.	5	Petterssonetal.1993
U	Australia	.	field	resident	Waterlily	Dicot	*Nymphaeaviolacea*	.	.	.	.	.	leaf	.	.	5	Petterssonetal.1993
U	California	Kesterson	field	248days	Grass	Monocot	*Elytrigiapontica*	7.8	.	14	6	.	leaf/stem	0.2	.	.	Retanaetal.1993
U	California	Kesterson	field	248days	Grass	Monocot	*Oryzopsishymenoides*	7.8	.	14	6	.	leaf/stem	0.8	.	.	Retanaetal.1993
U	California	Kesterson	field	248days	Grass	Monocot	*Sporobolusairoides*	7.8	.	14	6	.	leaf/stem	0.1	.	.	Retanaetal.1993
U	California	Kesterson	field	248days	Seaccumulator	Dicot	*Astragalusbisulcatus*	7.8	.	14	6	.	leaf/stem	0.4	.	.	Retanaetal.1993
U	California	Kesterson	field	248days	Seaccumulator	Dicot	*Astragalusracemosus*	7.8	.	14	6	.	leaf/stem	0.4	.	.	Retanaetal.1993
U	California	Kesterson	field	248days	Grass	Monocot	*Elytrigiapontica*	7.8	.	14	6	.	root	17.5	.	.	Retanaetal.1993
U	California	Kesterson	field	248days	Grass	Monocot	*Oryzopsishymenoides*	7.8	.	14	6	.	root	31.7	.	.	Retanaetal.1993
U	California	Kesterson	field	248days	Grass	Monocot	*Sporobolusairoides*	7.8	.	14	6	.	root	8.9	.	.	Retanaetal.1993
U	California	Kesterson	field	248days	Seaccumulator	Dicot	*Astragalusbisulcatus*	7.8	.	14	6	.	root	29.9	.	.	Retanaetal.1993
U	California	Kesterson	field	248days	Seaccumulator	Dicot	*Astragalusracemosus*	7.8	.	14	6	.	root	28.3	.	.	Retanaetal.1993
U	.	.	.	.	Annuals	Dicot	.	.	.	.	5	.	.	.	.	.	SheppardandEvenden1988
U	.	.	.	.	Annuals	Dicot	.	.	.	.	5	.	.	.	.	.	SheppardandEvenden1988
U	.	.	.	.	Cereals	Monocot	.	.	.	.	5	.	.	.	.	.	SheppardandEvenden1988
U	.	.	.	.	Cereals	Monocot	.	.	.	.	5	.	.	.	.	.	SheppardandEvenden1988

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
U	.	.	.	.	Forage	Monocot	.	.	.	.	5	.	.	.	.	.	SheppardandEvenden1988
U	.	.	.	.	Forage	Monocot	.	.	.	.	5	.	.	.	.	.	SheppardandEvenden1988
U	.	.	.	.	Forage	Monocot	.	.	.	.	5	.	.	.	.	.	SheppardandEvenden1988
U	.	.	.	.	Fruits	Dicot	.	.	.	.	5	.	.	.	.	.	SheppardandEvenden1988
U	.	.	.	.	Rootcrops	Dicot	.	.	.	.	5	.	.	.	.	.	SheppardandEvenden1988
U	.	.	.	.	Rootcrops	Dicot	.	.	.	.	5	.	.	.	.	.	SheppardandEvenden1988
U	.	.	.	.	Rootcrops	Dicot	.	.	.	.	5	.	.	.	.	.	SheppardandEvenden1988
U	.	.	.	.	Shrubs	Dicot	.	.	.	.	5	.	.	.	.	.	SheppardandEvenden1988
U	.	.	.	.	Trees	Dicot	.	.	.	.	5	.	.	.	.	.	SheppardandEvenden1988
U	.	.	.	.	Trees	Dicot	.	.	.	.	5	.	.	.	.	.	SheppardandEvenden1988
U	.	.	.	.	Vegetables	Dicot	.	.	.	.	5	.	.	.	.	.	SheppardandEvenden1988
U	.	.	.	.	Vegetables	Dicot	.	.	.	.	5	.	.	.	.	.	SheppardandEvenden1988
U	Fixedwatertable	16-20	lab	53days	Barley	Monocot	*Hordeumvulgare*	8.1	.	60	325	.	leaf/stem	7.33	.	4	SheppardandEvenden1985
U	Fluctuatingwatertable	16-20	lab	53days	Barley	Monocot	*Hordeumvulgare*	8.1	.	60	487	.	leaf/stem	1.38	.	4	SheppardandEvenden1985
U	Fixedwatertable	Control	lab	53days	Barley	Monocot	*Hordeumvulgare*	8.1	.	60	325	.	leaf/stem	0.13	.	4	SheppardandEvenden1985
U	Fluctuatingwatertable	Control	lab	53days	Barley	Monocot	*Hordeumvulgare*	8.1	.	60	487	.	leaf/stem	0.15	.	4	SheppardandEvenden1985
U	Canada	.	field	resident	Blueberry	Dicot	*Vacciniumangustifolium*	.	.	.	1.1	.	leaf	0.01	U	.	SheppardandEvenden1990
U	Canada	loam	lab	74day	Alfalfa	Dicot	*Medicagosativa*	8.0	.	60.0	50	.	leaf/stem	0.11	.	.	Sheppardetal.1984
U	Canada	loam	lab	74day	Alfalfa	Dicot	*Medicagosativa*	8.0	.	60.0	100	.	leaf/stem	0.52	.	.	Sheppardetal.1984
U	Canada	sand	lab	74day	Alfalfa	Dicot	*Medicagosativa*	8.6	.	1.6	50	.	leaf/stem	3.20	.	.	Sheppardetal.1984
U	Canada	sand	lab	74day	Alfalfa	Dicot	*Medicagosativa*	8.6	.	1.6	100	.	leaf/stem	20.05	.	.	Sheppardetal.1984
U	Canada	loam	lab	74day	beet	Dicot	*Betavulgaris*	8.0	.	60.0	50	.	leaf/stem	0.46	.	.	Sheppardetal.1984
U	Canada	loam	lab	74day	beet	Dicot	*Betavulgaris*	8.0	.	60.0	100	.	leaf/stem	0.80	.	.	Sheppardetal.1984
U	Canada	sand	lab	74day	beet	Dicot	*Betavulgaris*	8.6	.	1.6	50	.	leaf/stem	13.05	.	.	Sheppardetal.1984
U	Canada	sand	lab	74day	beet	Dicot	*Betavulgaris*	8.6	.	1.6	100	.	leaf/stem	10.95	.	.	Sheppardetal.1984
U	lab	3	lab	.	Blueberry	Dicot	*Vacciniumangustifolium*	4.9	.	5.8	0.7	.	leaf	.	.	3	Sheppardetal.1989
U	lab	4	lab	.	spinach	Dicot	*Spinaciaoleracea*	5.5	.	120	1.5	.	leaf	.	.	3	Sheppardetal.1989
U	lab	1	lab	.	spinach	Dicot	*Spinaciaoleracea*	7	.	28	2.1	.	leaf	.	.	3	Sheppardetal.1989
U	lab	2	lab	.	Barley	Monocot	*Hordiumsp.*	7.3	.	17	2.7	.	seed	.	.	3	Sheppardetal.1989
U	lab	2	lab	.	Corn	Monocot	*ZeaMays*	7.3	.	17	2.7	.	seed	.	.	3	Sheppardetal.1989
U	lab	4	lab	.	Corn	Monocot	*ZeaMays*	5.5	.	120	1.5	.	seed	.	.	3	Sheppardetal.1989
U	lab	2	lab	.	wildrice	Monocot	*Zizaniaaquatica*	7.3	.	17	2.7	.	seed	.	.	3	Sheppardetal.1989
U	lab	2	lab	.	potato	Dicot	*Solanumtuberosum*	7.3	.	17	2.7	.	root	.	.	3	Sheppardetal.1989
U	lab	3	lab	.	potato	Dicot	*Solanumtuberosum*	4.9	.	5.8	0.7	.	root	.	.	3	Sheppardetal.1989
U	lab	1	lab	.	Radish	Dicot	*Raphanussativus*	7	.	28	2.1	.	root	.	.	.	Sheppardetal.1989
U	lab	2	lab	.	Radish	Dicot	*Raphanussativus*	7.3	.	17	2.7	.	root	.	.	.	Sheppardetal.1989
U	lab	3	lab	.	Radish	Dicot	*Raphanussativus*	4.9	.	5.8	0.7	.	root	.	.	.	Sheppardetal.1989
U	lab	4	lab	.	Radish	Dicot	*Raphanussativus*	5.5	.	120	1.5	.	root	.	.	.	Sheppardetal.1989
U	Ontario	5	lab	.	Radish	Dicot	*Raphanussativus*	7.4	.	9.7	6.4	.	root	.	.	.	Sheppardetal.1989
U	Ontario	7	lab	.	Radish	Dicot	*Raphanussativus*	6.6	.	10.8	25	.	root	.	.	.	Sheppardetal.1989
U	Ontario	8	lab	.	Radish	Dicot	*Raphanussativus*	6.5	.	12.6	33	.	root	.	.	.	Sheppardetal.1989
U	Ontario	9	lab	.	Radish	Dicot	*Raphanussativus*	7.1	.	13.4	76	.	root	.	.	.	Sheppardetal.1989
V	Reisenberg	100mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.7	4.9	21.0	59.3	.	leaf	0.76	.	.	Lombietal.1998
V	Untertiefenbach	100mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	80.66	.	leaf	0.28	.	.	Lombietal.1998
V	Weyersdorf	100mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	6.9	3.5	10.9	80.7	.	leaf	1.31	.	.	Lombietal.1998
V	Reisenberg	150mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.7	4.9	21.0	71.0	.	leaf	1.87	.	.	Lombietal.1998
V	Untertiefenbach	150mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	113.3	.	leaf	0.71	.	.	Lombietal.1998
V	Reisenberg	50mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.7	4.9	21.0	40.0	.	leaf	0.36	.	.	Lombietal.1998
V	Untertiefenbach	50mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	59.67	.	leaf	0.30	.	.	Lombietal.1998
V	Weyersdorf	50mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	6.9	3.5	10.9	55.0	.	leaf	0.26	.	.	Lombietal.1998
V	Reisenberg	Control	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.7	4.9	21.0	20.0	.	leaf	0.13	.	.	Lombietal.1998
V	Untertiefenbach	Control	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	38.67	.	leaf	0.10	.	.	Lombietal.1998
V	Weyersdorf	Control	lab	40day	sunflower	Dicot	*Helianthusannuus*	6.9	3.5	10.9	29.7	.	leaf	0.17	.	.	Lombietal.1998
V	Reisenberg	100mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.7	4.9	21.0	59.3	.	seed	0.1	U	.	Lombietal.1998

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
V	Untertiefenbach	100mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	80.66	.	seed	0.1	U	.	Lombietal.1998
V	Weyersdorf	100mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	6.9	3.5	10.9	80.7	.	seed	0.1	U	.	Lombietal.1998
V	Reisenberg	150mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.7	4.9	21.0	71.0	.	seed	0.1	U	.	Lombietal.1998
V	Untertiefenbach	150mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	113.3	.	seed	0.1	U	.	Lombietal.1998
V	Reisenberg	50mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.7	4.9	21.0	40.0	.	seed	0.1	U	.	Lombietal.1998
V	Untertiefenbach	50mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	59.67	.	seed	0.1	U	.	Lombietal.1998
V	Weyersdorf	50mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	6.9	3.5	10.9	55.0	.	seed	0.1	U	.	Lombietal.1998
V	Reisenberg	Control	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.7	4.9	21.0	20.0	.	seed	0.1	U	.	Lombietal.1998
V	Untertiefenbach	Control	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	38.67	.	seed	0.1	U	.	Lombietal.1998
V	Weyersdorf	Control	lab	40day	sunflower	Dicot	*Helianthusannuus*	6.9	3.5	10.9	29.7	.	seed	0.1	U	.	Lombietal.1998
V	Oklahoma	GRID3	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.6	.	30.7	28.6	.	seed	0.2	.	.	PTI1995
V	Oklahoma	GRID4	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	5.95	.	20.95	30.85	.	seed	0.4	.	.	PTI1995
V	Oklahoma	TRAP1	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.4	.	14.1	57.9	.	seed	57.9	.	.	PTI1995
V	Oklahoma	TRAP2	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6	.	31.7	28.4	.	seed	28.4	.	.	PTI1995
V	Oklahoma	TRAP2	field	resident	Greenbriar	Monocot	*Smilaxbona-nox*	6	.	31.7	28.4	.	seed	28.4	.	.	PTI1995
V	Oklahoma	GRID1	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7.1	.	21.6	20.7	.	seed	0.2	.	.	PTI1995
V	Oklahoma	GRID2	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.1	.	36.3	30.4	.	seed	0.1	.	.	PTI1995
V	Oklahoma	GRID3	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.6	.	30.7	28.6	.	seed	0.1	.	.	PTI1995
V	Oklahoma	TERA	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7	.	32.6	28.25	.	seed	28.25	.	.	PTI1995
V	Oklahoma	TERB	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.5	.	20.3	41.2	.	seed	41.2	.	.	PTI1995
V	Oklahoma	TERC	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.8	.	18.8	39.65	.	seed	39.65	.	.	PTI1995
V	Oklahoma	GRID1	field	resident	Millet	Monocot	*Panicumvirgatum*	7.1	.	21.6	20.7	.	seed	0.03	.	.	PTI1995
V	Oklahoma	GRID2	field	resident	Millet	Monocot	*Panicumvirgatum*	6.1	.	36.3	30.4	.	seed	0.3	.	.	PTI1995
V	Oklahoma	GRID4	field	resident	Millet	Monocot	*Panicumvirgatum*	5.95	.	20.95	30.85	.	seed	0.1	.	.	PTI1995
V	Oklahoma	TERA	field	resident	Millet	Monocot	*Panicumvirgatum*	7	.	32.6	28.25	.	seed	28.25	.	.	PTI1995
V	Oklahoma	TERB	field	resident	Millet	Monocot	*Panicumvirgatum*	6.5	.	20.3	41.2	.	seed	41.2	.	.	PTI1995
V	Oklahoma	TERC	field	resident	Millet	Monocot	*Panicumvirgatum*	6.8	.	18.8	39.65	.	seed	39.65	.	.	PTI1995
V	Oklahoma	GRID2	field	resident	Pigweed	Dicot	*Amaranthuspalmeri*	6.1	.	36.3	30.4	.	seed	0.2	.	.	PTI1995
V	Oklahoma	GRID1	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	7.1	.	21.6	20.7	.	seed	0.3	.	.	PTI1995
V	Oklahoma	GRID3	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.6	.	30.7	28.6	.	seed	0.2	.	.	PTI1995
V	Oklahoma	GRID4	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	5.95	.	20.95	30.85	.	seed	0.2	.	.	PTI1995
V	Oklahoma	TERA	field	resident	Ragweed	Dicot	*Ambrosiapsilostachya*	7	.	32.6	28.25	.	seed	28.25	.	.	PTI1995
V	Oklahoma	TERB	field	resident	Ragweed	Dicot	*Ambrosiapsilostachya*	6.5	.	20.3	41.2	.	seed	41.2	.	.	PTI1995
V	Oklahoma	TERC	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.8	.	18.8	39.65	.	seed	39.65	.	.	PTI1995
V	Oklahoma	TRAP1	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.4	.	14.1	57.9	.	seed	57.9	.	.	PTI1995
V	Oklahoma	TRAP1	field	resident	Ragweed	Dicot	*Ambrosiatrifida*	6.4	.	14.1	57.9	.	seed	57.9	.	.	PTI1995
V	Oklahoma	TRAP2	field	resident	Ragweed	Dicot	*Ambrosiatrifida*	6	.	31.7	28.4	.	seed	28.4	.	.	PTI1995
V	Wyoming	Reference	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	20.76	.	leaf	0.4	.	.	RamirezandRogers2000
V	Wyoming	StudyArea	field	resident	Dandelion	Dicot	*Taraxacumofficinale*	.	.	.	32.66	.	leaf	0.4	.	.	RamirezandRogers2000
V	Wyoming	Reference	field	resident	KentuckyBluegrass	Monocot	*PoaPratensis*	.	.	.	20.76	.	leaf	0.4	.	.	RamirezandRogers2000
V	Wyoming	StudyArea	field	resident	Pondweed	Monocot	*Potamogetonsp*	.	.	.	0.01	.	leaf	9.99	.	.	RamirezandRogers2000
V	California	Kesterson	field	248days	Grass	Monocot	*Elytrigiapontica*	7.8	.	14	15.8	.	leaf/stem	2.2	.	.	Retanaetal.1993
V	California	Kesterson	field	248days	Grass	Monocot	*Oryzopsishymenoides*	7.8	.	14	15.8	.	leaf/stem	2.2	.	.	Retanaetal.1993
V	California	Kesterson	field	248days	Grass	Monocot	*Sporobolusairoides*	7.8	.	14	15.8	.	leaf/stem	1.7	.	.	Retanaetal.1993
V	California	Kesterson	field	248days	Seaccumulator	Dicot	*Astragalusbisulcatus*	7.8	.	14	15.8	.	leaf/stem	0.8	.	.	Retanaetal.1993
V	California	Kesterson	field	248days	Seaccumulator	Dicot	*Astragalusracemosus*	7.8	.	14	15.8	.	leaf/stem	0.1	.	.	Retanaetal.1993
V	California	Kesterson	field	248days	Grass	Monocot	*Elytrigiapontica*	7.8	.	14	15.8	.	root	5.9	.	.	Retanaetal.1993
V	California	Kesterson	field	248days	Grass	Monocot	*Oryzopsishymenoides*	7.8	.	14	15.8	.	root	17.1	.	.	Retanaetal.1993
V	California	Kesterson	field	248days	Grass	Monocot	*Sporobolusairoides*	7.8	.	14	15.8	.	root	4.5	.	.	Retanaetal.1993
V	California	Kesterson	field	248days	Seaccumulator	Dicot	*Astragalusbisulcatus*	7.8	.	14	15.8	.	root	6.8	.	.	Retanaetal.1993
V	California	Kesterson	field	248days	Seaccumulator	Dicot	*Astragalusracemosus*	7.8	.	14	15.8	.	root	6.4	.	.	Retanaetal.1993
Zn	California	Kesterson	field	resident	BirdfootTrefoil	Dicot	*Lotuscorniculatus*	.	.	.	46	.	leaf/stem	15	.	.	Banuelosetal.1999
Zn	California	Kesterson	field	resident	Mustard	Dicot	*Brassicajuncea*	.	.	.	46	.	leaf/stem	25	.	.	Banuelosetal.1999
Zn	California	Kesterson	field	resident	Rose-Mallow	Dicot	*Hibiscuscanabinus*	.	.	.	46	.	leaf/stem	43	.	.	Banuelosetal.1999

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
Zn	California	Kesterson	field	resident	TallFescue	Monocot	Festucaarundinacea	.	.	.	46	.	leaf/stem	10	.	.	Banuelosetal.1999
Zn	California	Kesterson	field	resident	BirdfootTrefoil	Dicot	Lotuscorniculatus	.	.	.	46	.	root	20	.	.	Banuelosetal.1999
Zn	California	Kesterson	field	resident	Mustard	Dicot	Brassicajuncea	.	.	.	46	.	root	20	.	.	Banuelosetal.1999
Zn	California	Kesterson	field	resident	Rose-Mallow	Dicot	Hibiscuscanabinus	.	.	.	46	.	root	28	.	.	Banuelosetal.1999
Zn	California	Kesterson	field	resident	TallFescue	Monocot	Festucaarundinacea	.	.	.	46	.	root	22	.	.	Banuelosetal.1999
Zn	Pennsylvania	Palmerton	field	resident	acorns/berries	Dicot	mixedfruitsandacorns	5.9	12	14	2900	.	fruit/seed	59	.	3	Beyeretal.1985
Zn	Pennsylvania	BakeOvenKnob	field	resident	acorns/berries	Dicot	mixedfruitsandacorns	5	23	19	230	.	fruit/seed	27	.	4	Beyeretal.1985
Zn	Maryland	1	field	resident	CommonReed	Monocot	Phragmitesaustralis	3	.	.	74	.	leaf	5.4	.	.	Beyeretal.1990
Zn	Delaware	2	field	resident	CommonReed	Monocot	Phragmitesaustralis	5.2	.	.	120	.	leaf	9.4	.	.	Beyeretal.1990
Zn	Maryland	3	field	resident	CommonReed	Monocot	Phragmitesaustralis	3.1	.	.	83	.	leaf	10	.	.	Beyeretal.1990
Zn	Pennsylvania	4	field	resident	CommonReed	Monocot	Phragmitesaustralis	6.3	.	.	240	.	leaf	11	.	.	Beyeretal.1990
Zn	Maryland	5	field	resident	CommonReed	Monocot	Phragmitesaustralis	3.6	.	.	200	.	leaf	21	.	.	Beyeretal.1990
Zn	India	Polluted	field	resident	Rice	Monocot	Oryzasativa	.	.	.	52	.	leaf	15	.	.	Fazelietal.1998
Zn	India	Unpolluted	field	resident	Rice	Monocot	Oryzasativa	.	.	.	45	.	leaf	12	.	.	Fazelietal.1998
Zn	India	Polluted	field	resident	Rice	Monocot	Oryzasativa	.	.	.	52	.	seed	19	.	.	Fazelietal.1998
Zn	India	Unpolluted	field	resident	Rice	Monocot	Oryzasativa	.	.	.	45	.	seed	17	.	.	Fazelietal.1998
Zn	Spain	1)Roadsideedge	field	resident	Ryegrass	Monocot	Loliumperenne	7.8	7	18	2618	.	wholeplant	120	.	.	Garciaetal.1996
Zn	Spain	2)Roadsideedge	field	resident	Ryegrass	Monocot	Loliumperenne	7.4	9.5	29	87	.	wholeplant	23	.	.	Garciaetal.1996
Zn	Spain	3)Roadsideedge	field	resident	Ryegrass	Monocot	Loliumperenne	8.1	4.2	15	485	.	wholeplant	34.8	.	.	Garciaetal.1996
Zn	Spain	4)Roadsideedge	field	resident	Ryegrass	Monocot	Loliumperenne	8	2.7	18	125	.	wholeplant	42.4	.	.	Garciaetal.1996
Zn	Spain	5)Roadsideedge	field	resident	Ryegrass	Monocot	Loliumperenne	7.6	10.6	27	286	.	wholeplant	33.5	.	.	Garciaetal.1996
Zn	Spain	6)Roadsideedge	field	resident	Ryegrass	Monocot	Loliumperenne	8.2	4.5	16	439	.	wholeplant	42.9	.	.	Garciaetal.1996
Zn	Spain	7)Roadsideedge	field	resident	Ryegrass	Monocot	Loliumperenne	7.9	7.4	19	441	.	wholeplant	45.6	.	.	Garciaetal.1996
Zn	Spain	8)Roadsideedge	field	resident	Ryegrass	Monocot	Loliumperenne	7.8	5	16	262	.	wholeplant	32.8	.	.	Garciaetal.1996
Zn	Spain	1)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	Loliumperenne	7.6	6.2	36	113	.	wholeplant	24.7	.	.	Garciaetal.1996
Zn	Spain	2)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	Loliumperenne	5.7	6.4	34	52	.	wholeplant	28.7	.	.	Garciaetal.1996
Zn	Spain	3)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	Loliumperenne	7	10.6	48	186	.	wholeplant	26.5	.	.	Garciaetal.1996
Zn	Spain	4)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	Loliumperenne	7.7	3.1	27	108	.	wholeplant	43	.	.	Garciaetal.1996
Zn	Spain	5)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	Loliumperenne	6.9	24.6	51	279	.	wholeplant	35.5	.	.	Garciaetal.1996
Zn	Spain	6)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	Loliumperenne	6.9	6.4	30	170	.	wholeplant	32.6	.	.	Garciaetal.1996
Zn	Spain	7)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	Loliumperenne	7.7	8.5	26	398	.	wholeplant	33	.	.	Garciaetal.1996
Zn	Spain	8)3mFromRoadsideEdge	field	resident	Ryegrass	Monocot	Loliumperenne	7.9	5.2	24	96	.	wholeplant	21.5	.	.	Garciaetal.1996
Zn	Korea	miningsite	field	resident	Corn	Monocot	Zeamays	5.75	.	5.2	8300	.	seed	38	.	8	JungandThornton1996
Zn	Korea	after30days	field	resident	Rice	Monocot	Oryzasativa	5.5	.	13.2	627	.	leaf/stem	95	.	14	JungandThornton1997
Zn	Korea	after80days	field	resident	Rice	Monocot	Oryzasativa	5.5	.	11.3	507	.	leaf/stem	74	.	31	JungandThornton1997
Zn	Korea	after150days	field	resident	Rice	Monocot	Oryzasativa	5.3	.	11.3	681	.	seed	137	.	.	JungandThornton1997
Zn	Reisenberg	300mg/kg	lab	40day	sunflower	Dicot	Helianthusannuus	7.7	4.9	21.0	261.3	.	leaf	76.1	.	.	Lombietal.1998
Zn	Untertiefenbach	300mg/kg	lab	40day	sunflower	Dicot	Helianthusannuus	7.5	6.0	27.1	245.3	.	leaf	62.76	.	.	Lombietal.1998
Zn	Weyersdorf	300mg/kg	lab	40day	sunflower	Dicot	Helianthusannuus	6.9	3.5	10.9	249.7	.	leaf	148.0	.	.	Lombietal.1998
Zn	Reisenberg	600mg/kg	lab	40day	sunflower	Dicot	Helianthusannuus	7.7	4.9	21.0	478.0	.	leaf	103	.	.	Lombietal.1998
Zn	Untertiefenbach	600mg/kg	lab	40day	sunflower	Dicot	Helianthusannuus	7.5	6.0	27.1	408.6	.	leaf	92.47	.	.	Lombietal.1998
Zn	Weyersdorf	600mg/kg	lab	40day	sunflower	Dicot	Helianthusannuus	6.9	3.5	10.9	412.3	.	leaf	660.3	.	.	Lombietal.1998
Zn	Reisenberg	900mg/kg	lab	40day	sunflower	Dicot	Helianthusannuus	7.7	4.9	21.0	626.0	.	leaf	127	.	.	Lombietal.1998
Zn	Untertiefenbach	900mg/kg	lab	40day	sunflower	Dicot	Helianthusannuus	7.5	6.0	27.1	636.3	.	leaf	161.6	.	.	Lombietal.1998
Zn	Reisenberg	Control	lab	40day	sunflower	Dicot	Helianthusannuus	7.7	4.9	21.0	73.7	.	leaf	41.5	.	.	Lombietal.1998
Zn	Untertiefenbach	Control	lab	40day	sunflower	Dicot	Helianthusannuus	7.5	6.0	27.1	87.00	.	leaf	32.1	.	.	Lombietal.1998
Zn	Weyersdorf	Control	lab	40day	sunflower	Dicot	Helianthusannuus	6.9	3.5	10.9	64.0	.	leaf	26.9	.	.	Lombietal.1998
Zn	Reisenberg	300mg/kg	lab	40day	sunflower	Dicot	Helianthusannuus	7.7	4.9	21.0	261.3	.	seed	58.3	.	.	Lombietal.1998
Zn	Untertiefenbach	300mg/kg	lab	40day	sunflower	Dicot	Helianthusannuus	7.5	6.0	27.1	245.3	.	seed	76.67	.	.	Lombietal.1998
Zn	Weyersdorf	300mg/kg	lab	40day	sunflower	Dicot	Helianthusannuus	6.9	3.5	10.9	249.7	.	seed	81.0	.	.	Lombietal.1998
Zn	Reisenberg	600mg/kg	lab	40day	sunflower	Dicot	Helianthusannuus	7.7	4.9	21.0	478.0	.	seed	82.0	.	.	Lombietal.1998
Zn	Untertiefenbach	600mg/kg	lab	40day	sunflower	Dicot	Helianthusannuus	7.5	6.0	27.1	408.6	.	seed	61.33	.	.	Lombietal.1998
Zn	Weyersdorf	600mg/kg	lab	40day	sunflower	Dicot	Helianthusannuus	6.9	3.5	10.9	412.3	.	seed	94	.	.	Lombietal.1998
Zn	Reisenberg	900mg/kg	lab	40day	sunflower	Dicot	Helianthusannuus	7.7	4.9	21.0	626.0	.	seed	59.0	.	.	Lombietal.1998

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
Zn	Untertiefenbach	900mg/kg	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	636.3	.	seed	86.00	.	.	Lombietal.1998
Zn	Reisenberg	Control	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.7	4.9	21.0	73.7	.	seed	70.7	.	.	Lombietal.1998
Zn	Untertiefenbach	Control	lab	40day	sunflower	Dicot	*Helianthusannuus*	7.5	6.0	27.1	87.00	.	seed	67.33	.	.	Lombietal.1998
Zn	Weyersdorf	Control	lab	40day	sunflower	Dicot	*Helianthusannuus*	6.9	3.5	10.9	64.0	.	seed	65.33	.	.	Lombietal.1998
Zn	Montana	milltown(reference)	field	resident	Grass	Monocot	.	.	.	.	49.3	.	leaf	36.2	.	1	Pascoeetal.1996
Zn	Montana	milltown(reference)	field	resident	forb	Dicot	.	.	.	.	49.3	.	leaf/stem	12.25	.	2	Pascoeetal.1996
Zn	Montana	milltown	field	resident	Grass	Monocot	.	.	.	.	1949.5	.	leaf	153.7	.	4	Pascoeetal.1996
Zn	Montana	milltown	field	resident	forb	Dicot	.	.	.	.	1949.5	.	leaf/stem	224.1	.	20	Pascoeetal.1996
Zn	Germany	Br	field	resident	greenalgae	Chlorophyta	.	.	.	.	172.6	.	wholeplant	156.9	.	.	Posthuma1990
Zn	Netherlands	Bu	field	resident	greenalgae	Chlorophyta	.	.	.	.	949.5	.	wholeplant	906.3	.	.	Posthuma1990
Zn	Netherlands	Mo	field	resident	greenalgae	Chlorophyta	.	.	.	.	381.8	.	wholeplant	294.3	.	.	Posthuma1990
Zn	Belgium	Pl	field	resident	greenalgae	Chlorophyta	.	.	.	.	4915.4	.	wholeplant	406	.	.	Posthuma1990
Zn	Netherlands	Ro	field	resident	greenalgae	Chlorophyta	.	.	.	.	32.7	.	wholeplant	34.7	.	.	Posthuma1990
Zn	Germany	St	field	resident	greenalgae	Chlorophyta	.	.	.	.	1560.2	.	wholeplant	331.5	.	.	Posthuma1990
Zn	Oklahoma	GRID3	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.6	.	30.7	1530	.	seed	626	.	.	PTI1995
Zn	Oklahoma	GRID4	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	5.95	.	20.95	2135	.	seed	393	.	.	PTI1995
Zn	Oklahoma	TRAP1	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6.4	.	14.1	7170	.	seed	7170	.	.	PTI1995
Zn	Oklahoma	TRAP2	field	resident	BeggersTick	Dicot	*Bidenspolylepis*	6	.	31.7	2270	.	seed	2270	.	.	PTI1995
Zn	Oklahoma	TRAP2	field	resident	Greenbriar	Monocot	*Smilaxbona-nox*	6	.	31.7	2270	.	seed	2270	.	.	PTI1995
Zn	Oklahoma	GRID1	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7.1	.	21.6	3210	.	seed	417	.	.	PTI1995
Zn	Oklahoma	GRID2	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.1	.	36.3	3750	.	seed	114	.	.	PTI1995
Zn	Oklahoma	GRID3	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.6	.	30.7	1530	.	seed	103	.	.	PTI1995
Zn	Oklahoma	TERA	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	7	.	32.6	183	.	seed	183	.	.	PTI1995
Zn	Oklahoma	TERB	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.5	.	20.3	416	.	seed	416	.	.	PTI1995
Zn	Oklahoma	TERC	field	resident	IndianGrass	Monocot	*Sorghastrumnutans*	6.8	.	18.8	199	.	seed	199	.	.	PTI1995
Zn	Oklahoma	GRID1	field	resident	Millet	Monocot	*Panicumvirgatum*	7.1	.	21.6	3210	.	seed	496	.	.	PTI1995
Zn	Oklahoma	GRID2	field	resident	Millet	Monocot	*Panicumvirgatum*	6.1	.	36.3	3750	.	seed	133	.	.	PTI1995
Zn	Oklahoma	GRID4	field	resident	Millet	Monocot	*Panicumvirgatum*	5.95	.	20.95	2135	.	seed	365	.	.	PTI1995
Zn	Oklahoma	TERA	field	resident	Millet	Monocot	*Panicumvirgatum*	7	.	32.6	183	.	seed	183	.	.	PTI1995
Zn	Oklahoma	TERB	field	resident	Millet	Monocot	*Panicumvirgatum*	6.5	.	20.3	416	.	seed	416	.	.	PTI1995
Zn	Oklahoma	TERC	field	resident	Millet	Monocot	*Panicumvirgatum*	6.8	.	18.8	199	.	seed	199	.	.	PTI1995
Zn	Oklahoma	GRID2	field	resident	Pigweed	Dicot	*Amaranthuspalmeri*	6.1	.	36.3	3750	.	seed	1880	.	.	PTI1995
Zn	Oklahoma	GRID1	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	7.1	.	21.6	3210	.	seed	662	.	.	PTI1995
Zn	Oklahoma	GRID3	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.6	.	30.7	1530	.	seed	1650	.	.	PTI1995
Zn	Oklahoma	GRID4	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	5.95	.	20.95	2135	.	seed	1450	.	.	PTI1995
Zn	Oklahoma	TERA	field	resident	Ragweed	Dicot	*Ambrosiapsilostachya*	7	.	32.6	183	.	seed	183	.	.	PTI1995
Zn	Oklahoma	TERB	field	resident	Ragweed	Dicot	*Ambrosiapsilostachya*	6.5	.	20.3	416	.	seed	416	.	.	PTI1995
Zn	Oklahoma	TERC	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.8	.	18.8	199	.	seed	199	.	.	PTI1995
Zn	Oklahoma	TRAP1	field	resident	Ragweed	Dicot	*Ambrosiaartemisiifolia*	6.4	.	14.1	7170	.	seed	7170	.	.	PTI1995
Zn	Oklahoma	TRAP1	field	resident	Ragweed	Dicot	*Ambrosiatrifida*	6.4	.	14.1	7170	.	seed	7170	.	.	PTI1995
Zn	Oklahoma	TRAP2	field	resident	Ragweed	Dicot	*Ambrosiatrifida*	6	.	31.7	2270	.	seed	2270	.	.	PTI1995
Zn	Wyoming	Reference	field	resident	Alfalfa	Dicot	*Medicagosativa*	.	.	.	59.31	.	leaf	32.8	.	.	RamirezandRogers2000
Zn	Wyoming	Reference	field	resident	Brome	Monocot	*Bromussp.*	.	.	.	59.31	.	leaf	25.96	.	.	RamirezandRogers2000
Zn	Wyoming	StudyArea	field	resident	Brome	Monocot	*Bromussp.*	.	.	.	51.10	.	leaf	19.34	.	.	RamirezandRogers2000
Zn	Wyoming	StudyArea	field	resident	Dandelion	Dicot	*Taraxacumofficinale*	.	.	.	51.10	.	leaf	17	.	.	RamirezandRogers2000
Zn	Wyoming	StudyArea	field	resident	FoxtailBarley	Dicot	*Hordiumjubatum*	.	.	.	51.10	.	leaf	17.25	.	.	RamirezandRogers2000
Zn	Wyoming	Reference	field	resident	KentuckyBluegrass	Monocot	*PoaPratensis*	.	.	.	59.31	.	leaf	28	.	.	RamirezandRogers2000
Zn	Wyoming	StudyArea	field	resident	Pondweed	Monocot	*Potamogetonsp*	.	.	.	0.02	.	leaf	31.69	.	.	RamirezandRogers2000
Zn	Canada	.	field	resident	Blueberry	Dicot	*Vacciniumangustifolium*	.	.	.	80	.	leaf	16	.	64	SheppardandEvenden1990
Zn	Colorado	.	field	resident	DevilsBitScabious	Dicot	*Succisapratensis*	6.48	.	.	155.7	.	leaf	115.77	.	15	SteinbornandBreen1999
Zn	Colorado	.	field	resident	Germander	Dicot	*Teucriumscorodonica*	6.34	.	.	299	.	leaf	721	.	15	SteinbornandBreen1999
Zn	Colorado	.	field	resident	Primrose	Dicot	*Primulavulgaris*	6.8	.	.	204	.	leaf	195.68	.	15	SteinbornandBreen1999
Zn	Colorado	.	field	resident	Moss	Bryophyte	*Rhytidiadelphusloreus*	7.13	.	.	200	.	leaf/stem	274	.	15	SteinbornandBreen1999
Zn	Colorado	.	field	resident	Stair-stepmoss	Bryophyte	*Hylocomiumsplendens*	6.54	.	.	230.6	.	leaf/stem	308	.	15	SteinbornandBreen1999

Appendix B-2. Literature-deriveddataforcalculationofsoil-plantcontaminantuptakefactors.

Analyte	Study Location	Sample Location	Lab/Field	Duration	Common Name	Monocot/ Dicot	Species	Soil pH	Percent Organic Matter	Cation Exchange Capacity	Soil Conc mg/kg dry wt	Soil Qualifier	tissue	Plant Conc mg/kg dry wt	Plant Qualifier	N	Reference
Zn	China	Futian	fielld	resident	Mangrove	Dicot	*Aegicerascorniculatum*	5.6	.	28.56	146.1	.	leaf	85.2	.	.	Tametal1995
Zn	China	Futian	fielld	resident	Mangrove	Dicot	*Kandeliacandel*	5.6	.	28.56	146.1	.	leaf	69.7	.	.	Tametal1995
Zr	Canada	.	field	resident	Blueberry	Dicot	*Vacciniumangustifolium*	.	.	.	93	.	leaf	0.1	.	14	SheppardandEvenden1990